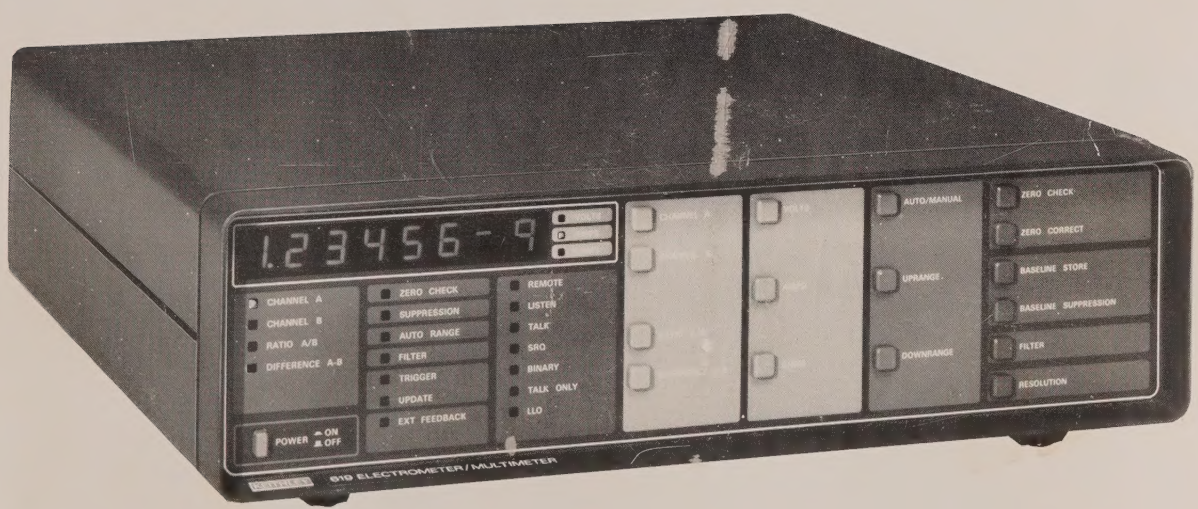
MAGNETICS LAB AREA 193S

KEITHLEY

Model 619 Electrometer/Multimeter Instruction Manual



Contains Operating and Servicing Information

Publication Date: February 1985
Document Number: 30914 Rev. F

MP MASTER
MA28544

WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment. During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the instrument, transportation prepaid, to the indicated service facility. Repairs will be made and the instrument returned, transportation prepaid. Repaired products are warranted for the balance of the original warranty period, or at least 90 days.

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from unauthorized modification or misuse of any product or part. This warranty also does not apply to fuses, batteries, or damage from battery leakage.

This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty of merchantability or fitness for a particular use. Keithley Instruments, Inc. shall not be liable for any indirect, special or consequential damages.

STATEMENT OF CALIBRATION

This instrument has been inspected and tested in accordance with specifications published by Keithley Instruments, Inc.

The accuracy and calibration of this instrument are traceable to the National Bureau of Standards through equipment which is calibrated at planned intervals by comparison to certified standards maintained in the Laboratories of Keithley Instruments, Inc.

KEITHLEY

Keithley Instruments, Inc./28775 Aurora Road/Cleveland, Ohio 44139/U.S.A./(216) 248-0400/Telex: 98-5469
WEST GERMANY: **Keithley Instruments GmbH**/Heiglhofstrasse 5/D-8000 München 70/314 289/Telex: 1345000
GREAT BRITAIN: **Keithley Instruments, Ltd.**/1, Boulton Road/Reading, Berkshire RG2 ONL/(0734) 86 12 87/Telex: 847047
FRANCE: **Keithley Instruments SARL**/2 Bis, Rue Léon Blum/B.P. 60/91121 Palaiseau Cedex/(6) 0115 155/Telex: 600933
NETHERLANDS: **Keithley Instruments BV**/Arkelsedijk 4/NL-4206 AC Gorinchem/(01830) 25577/Telex: 24 684
SWITZERLAND: **Keithley Instruments SA**/Kriesbachstr. 4/CH-8660 Dübendorf/01 821 94 44/Telex: 57 536
AUSTRIA: **Keithley Instruments Ges.m.b.H**/Döblinger Hauptstr. 32/A-1190 Wien/0222 314 289/Telex: 134500

Instruction Manual
Model 619
Electrometer/Multimeter

©1981, Keithley Instruments, Inc.
Cleveland, Ohio, U.S.A
Document Number 30914

SPECIFICATIONS

DC VOLTS

RANGE	MAXIMUM READING	ACCURACY 1 YR., 23° ±5°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0-18°C & 28-50°C ±(%rdg+counts)/°C
200mV	199.999×10^{-3}	0.01+25	0.002+30
2 V	1.99999	0.01+10	0.002+ 3
20 V	19.9999	0.02+10	0.002+ 0.3
200 V	199.999	0.02+10	0.002+ 0.3

INPUT CAPACITANCE: Less than or equal to 20pF.

INPUT RESISTANCE: Greater than or equal to 20TΩ.

NMRR: Greater than 55dB (greater than 80dB with FILTER).

CMRR: Greater than 100dB (greater than 125dB with FILTER).

ANALOG SETTLING TIME (to 0.1% of final value, unfiltered): Less than 5ms.

DC AMPS

RANGE	MAXIMUM READING	ACCURACY 1 YR., 23°±5°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0-18°C & 28-50°C ±(%rdg+counts)/°C	INVERTING FULL SCALE ANALOG OUTPUT
2 nA	1.99999×10^{-9}	0.35+65	0.02+30	0.2V
20 nA	19.9999×10^{-9}	0.35+35	0.02+ 3	2.0V
200 nA	199.999×10^{-9}	0.15+25	0.01+30	0.2V
2 μA	1.99999×10^{-6}	0.15+10	0.01+ 3	2.0V
20 μA	19.9999×10^{-6}	0.15+25	0.01+30	0.2V
200 μA	199.999×10^{-6}	0.15+10	0.01+ 3	2.0V
2mA	1.99999×10^{-3}	0.15+25	0.01+30	0.2V
20mA	19.9999×10^{-3}	0.15+10	0.01+ 3	2.0V
2 A	1.99999	0.15+25	0.01+20	None

INPUT VOLTAGE DROP: Less than 1mV at full-scale except less than 0.6V on 2A range.

ANALOG SETTLING TIME (to 0.1% of final value, unfiltered): 2nA through 2μA: 50ms; 20μA through 2A: 5ms.

NMRR: 2nA through 2μA: 70dB; 20μA through 2A: 55dB.

OHMS

RANGE	MAXIMUM READING	ACCURACY 1 YR., 23°±5°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0-18°C & 28-50°C ±(%rdg+counts)/°C	MAXIMUM OPEN-CIRCUIT VOLTAGE
2 kΩ	1.99999×10^{-3}	0.2 +25	0.01+30	5V
20 kΩ	19.9999×10^{-3}	0.2 +10	0.01+ 3	5V
200 kΩ	199.999×10^{-3}	0.15+25	0.01+30	5V
2MΩ	1.99999×10^{-6}	0.15+10	0.01+ 3	5V
20MΩ	19.9999×10^{-6}	0.35+25	0.02+30	5V
200MΩ	199.999×10^{-6}	0.35+10	0.02+ 3	5V
2 GΩ	1.99999×10^{-9}	0.35+10	0.02+ 0.3	300V
20 GΩ	19.9999×10^{-9}	1 +10	0.15+ 3	300V
200 GΩ	199.999×10^{-9}	4 +10	0.5 + 0.3	300V
2 TΩ	1.99999×10^{-12}	10 +10	0.5 + 0.3	300V

OHMS CURRENT SOURCES: 2kΩ, 20kΩ: 100μA.
200kΩ, 2MΩ: 1μA.
20MΩ, 2GΩ: 10nA.
20GΩ through 2TΩ: 100pA.

ANALOG OUTPUT: Analog output voltage level is the product of the Ohms current source and the resistance being measured.

ANALOG SETTLING TIMES:

To 0.1% of final value, unfiltered, with less than 100pF input capacitance:
2kΩ through 2MΩ: 5ms.
20MΩ: 20ms.
200MΩ: 200ms.

To 10% of final value, unfiltered, using 6191 Guarded Input Adapter with less than 1pF unguarded input capacitance:
2GΩ: 150ms.
20GΩ: 1.5s.
200GΩ: 15s.
2TΩ: 150s.

IEEE-488 BUS IMPLEMENTATION

(Requires installation of Model 6193):

Multiline Commands: DCL, LLO, SDC, GET.
Uniline Commands: IFC, REN, EOI, SRQ, ATN. Compatible with IEEE-488-1978 standard.

PROGRAMMABLE PARAMETERS:

Front Panel Controls: Function, Range, Filter, Zero Check, Zero Correct, Baseline Store, Baseline Suppress.

Internal Parameters: SRQ Response, Trigger Modes, Binary or ASCII Data Formats, number of readings to be stored, data terminators, reading rates, integration period.

ADDRESS MODES: TALK ONLY and ADDRESSABLE.

GENERAL

DISPLAY: Numeric; 0.56 in. LED digits, 4½-digit mantissa @ 6.2 rdg/s (5½ digits @ 2.4 rdg/s in high resolution mode), 2 digit exponent, decimal point, signed exponent and mantissa.

OVERRANGE INDICATION: Display reads OFLO.

MAXIMUM ALLOWABLE INPUT: 250V rms dc to 60Hz sinewave.

INPUT CURRENT (18°-28°C): Less than 0.4pA.

EXTERNAL TRIGGER: TTL compatible EXTERNAL TRIGGER and ELECTROMETER COMPLETE.

INPUT CONNECTORS (6194 Electrometer rear panel): 2A range: 5-way binding posts. All other functions and ranges via Teflon® insulated triaxial connector.

OUTPUT CONNECTORS: Analog: Amphenol Series 80 (Microphone), 6194 Electrometer rear panel. **IEEE:** Amphenol or Cinch Series 57, 6193 IEEE Interface rear panel. BNC (chassis isolated) connections for EXTERNAL TRIGGER and ELECTROMETER COMPLETE.

READING RATES

Programmed Reading Rate	Number Of Integrations Averaged	Time Per Integration (ms)	Trigger To First Byte† (ms)	Readings Per Second
S0	1	4.1	32 (18 binary)	40
S1	1	16.67*	35	21
S2	2	16.67*	80	10
S3	4	16.67*	168	5.4
S4	1	100	120	4.7
S5	2	100	328	2.4
S6	4	100	742	1.2
S7	8	100	1680	0.6
S8	16	100	3360	0.3
S9	32	100	6720	0.15

*20 @ 50Hz.

†Typical. Add an additional 42ms for first conversion on a new channel, 26ms for first conversion on a new range or function.

MAXIMUM ALLOWABLE COMMON MODE VOLTAGES:

Input LO (Channel A) to line ground: 250V rms, dc to 60Hz sinewave.
Input LO (Channel B) to line ground: 250V rms, dc to 60Hz sinewave.
Input LO (Channel A) to Input LO (Channel B): 250V rms, dc to 60Hz sinewave.

WARMUP: 1 hour to rated accuracy.

POWER: 90-110, 105-125, 180-220, or 210-250V, 50 or 60Hz (internal switch selected). 75W max., 100VA max. (internally fan cooled).

ENVIRONMENTAL LIMITS: Operating: 0°-50°C, up to 35°C at 70% non-condensing R.H. **Storage:** −20°C to 70°C.

DIMENSIONS, WEIGHT: 432mm wide × 127mm high × 406mm deep (17 in. × 5 in. × 16 in.), stackable enclosure. Net weight, 9.8kg (22 lbs.) with Channel B Electrometer module and IEEE-488 Interface module.

ACCESSORIES SUPPLIED: One Model 6194 Electrometer Module and one Model 6011 Input Cable.

ACCESSORIES AVAILABLE: See Selector Guide on page 61.

Specifications subject to change without notice.

SAFETY PRECAUTIONS

The following safety precautions should be observed before operating the Model 619.

This instrument is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read over the manual carefully before operating this instrument.

Exercise extreme caution when a shock hazard is present at the instrument's input. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V rms or 42.4V peak are present. **A good safety practice is to expect that a hazardous voltage is present in any unknown circuit before measuring.**

Do not exceed 250V rms between input low and earth ground.

Inspect the test leads for possible wear, cracks or breaks before each use. If any defects are found, replace with test leads that have the same measure of safety as those supplied with the instrument.

For optimum safety do not touch the test leads or the instrument while power is applied to the circuit under test. Turn the power off and discharge all capacitors before connecting or disconnecting the instrument.

Do not touch any object which could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface, capable of withstanding the voltage being measured.

Do not exceed the instrument's maximum allowable input as defined in the specifications and operation section.

Safe operation and good measurement practice dictates use of an external resistor when necessary to limit input currents to less than 30mA (2A on the 2A current range).

Digitized by the Internet Archive
in 2025

https://archive.org/details/manualsplus_06106

TABLE OF CONTENTS

SECTION 1—GENERAL INFORMATION

1.1	Introduction	1-1
1.2	Features	1-1
1.3	Warranty Information	1-1
1.4	Manual Addenda	1-1
1.5	Safety Symbols and Terms	1-1
1.6	Specifications	1-1
1.6.1	Volts Specifications	1-1
1.6.2	Amps Specifications	1-2
1.6.3	Ohms Specifications	1-2
1.6.4	General Specifications	1-2
1.7	Using the Instruction Manual	1-3
1.8	Unpacking and Inspection	1-3
1.9	Getting Started	1-3
1.10	Preparation For Use	1-3
1.11	Repacking For Shipment	1-4
1.12	Accessories	1-4

SECTION 2—OPERATION

2.1	Introduction	2-1
2.2	Internal Programming	2-1
2.3	Power Up Procedures	2-1
2.4	Power Up Self Test And Display Messages	2-1
2.5	Front Panel Familiarization	2-2
2.5.1	Controls	2-2
2.5.2	Display And Indicators	2-2
2.5.3	Tilt Bail	2-3
2.6	Rear Panel Familiarization	2-3
2.6.1	Connectors And Terminals	2-3
2.6.2	Switches	2-4
2.6.3	Fuses	2-4
2.7	Function And Range Selection	2-4
2.7.1	Measuring Functions	2-4
2.7.2	Range Selection	2-4
2.8	Basic Measurement Techniques	2-5
2.8.1	Warm Up Period	2-5
2.8.2	Input Connections	2-5
2.8.3	Making Voltage Measurements	2-6
2.8.4	Making Current Measurements (2nA-20mA Ranges)	2-8
2.8.5	Current Measurements (2A Range)	2-9
2.8.6	Common Input For The Current Ranges	2-10
2.8.7	Resistance Measurements	2-10
2.8.8	Using The Ohms Function As A Current Source	2-12
2.9	Dual Channel Operation	2-12
2.9.1	Channel Selection	2-13
2.9.2	Ratio A/B And Difference A-B	2-13
2.9.3	Channel Isolation Considerations	2-13
2.9.4	Autoranging In The Dual Channel Mode	2-14
2.9.5	Speed Considerations	2-14

2.10 Using The Analog Output ... 2-14
2.10.1 Analog Output Connections ... 2-14
2.10.2 Guarded Operation ... 2-16
2.11 Using External Feedback ... 2-18
2.11.1 Electrometer Input Circuitry ... 2-18
2.11.2 Shielded Fixture Construction ... 2-19
2.11.3 External Feedback Procedure ... 2-19
2.11.4 Charge Measurement ... 2-19
2.11.5 Logarithmic Currents ... 2-21
2.11.6 Non-Decade Current Gains ... 2-22
2.12 Zero Check And Zero Correct ... 2-22
2.13 Baseline Store And Baseline Suppression ... 2-23
2.14 Filter ... 2-23
2.15 Resolution ... 2-24
2.16 External Triggering ... 2-24
2.16.1 External Trigger ... 2-24
2.16.2 Meter Complete ... 2-24
2.16.3 Trigger Example ... 2-25
2.17 Measurement Considerations ... 2-26
2.17.1 Ground Loops ... 2-26
2.17.2 Electrostatic Interference ... 2-26
2.17.3 Thermal EMFs ... 2-27
2.17.4 RFI ... 2-27
2.17.5 Leakage Resistance Effects ... 2-27
2.17.6 Input Capacitance Effects ... 2-28

SECTION 3—IEEE-488 PROGRAMMING

3.1 Introduction ... 3-1
3.2 Bus Description ... 3-1
3.3 IEEE-488 Bus Lines ... 3-1
3.3.1 Data Lines ... 3-2
3.3.2 Bus Management Lines ... 3-2
3.3.3 Handshake Lines ... 3-2
3.4 Bus Commands ... 3-3
3.4.1 Uniline Commands ... 3-3
3.4.2 Universal Commands ... 3-4
3.4.3 Addressed Commands ... 3-4
3.4.4 Unaddressed Commands ... 3-5
3.4.5 Device-Dependent Commands ... 3-5
3.5 Command Codes ... 3-5
3.6 Command Sequences ... 3-5
3.6.1 Addressed Command Sequence ... 3-7
3.6.2 Universal Command Sequence ... 3-7
3.6.3 Device-Dependent Command Sequence ... 3-7
3.7 Operational Considerations ... 3-7
3.7.1 Typical Controlled Systems ... 3-7
3.7.2 Bus Connections ... 3-8
3.7.3 Primary Address Settings ... 3-9
3.7.4 Secondary Addressing ... 3-10
3.7.5 Talk Only Mode ... 3-11
3.8 Controller Programming ... 3-11
3.8.1 Controller Handler Software ... 3-11
3.8.2 Interface BASIC Programming Statements ... 3-11
3.8.3 IEEE Command Groups ... 3-13

3.9 General Bus Command Programming ... 3-13
3.9.1 REN (Remote Enable) ... 3-13
3.9.2 IFC (Interface Clear) ... 3-14
3.9.3 LLO (Local Lockout) ... 3-14
3.9.4 GTL (Go To Local) and Local ... 3-15
3.9.5 DCL (Device Clear) ... 3-15
3.9.6 SDC (Selective Device Clear) ... 3-16
3.9.7 GET (Group Execute Trigger) ... 3-17
3.9.8 SPE, SPD (Serial Polling) ... 3-17
3.10 Device-Dependent Command Programming ... 3-18
3.10.1 Execute (X) ... 3-19
3.10.2 Function (F) ... 3-21
3.10.3 Range (R) ... 3-21
3.10.4 Data Format (D) ... 3-23
3.10.5 Reading Rate (S) ... 3-26
3.10.6 Trigger (T) ... 3-27
3.10.7 Zero Check and Zero Correct (C and Z) ... 3-28
3.10.8 Baseline Store (N) And Baseline Suppression (U) ... 3-29
3.10.9 Data Buffer Storage (Q) ... 3-31
3.10.10 SRQ Mode (M) And Status Byte Format ... 3-32
3.10.11 Filter (P) ... 3-34
3.10.12 Terminator (Y) ... 3-34
3.11 Machine Status Words ... 3-35
3.12 Data Transmission Times ... 3-37

SECTION 4—APPLICATIONS

4.1 Introduction ... 4-1
4.2 Insulation Resistance Measurements ... 4-1
4.3 High Impedance Voltmeter ... 4-5
4.4 Low-Level Leakage Current Measurements ... 4-5
4.5 Diode Characterization ... 4-7
4.6 Capacitor Leakage Measurements ... 4-9
4.7 Capacitance Measurement ... 4-9
4.8 Voltage Coefficient of High-Megohm Resistors ... 4-10
4.9 Static Charge Detection ... 4-10

SECTION 5—PERFORMANCE VERIFICATION

5.1 Introduction ... 5-1
5.2 Required Test Equipment ... 5-1
5.3 Environmental Conditions ... 5-1
5.4 Initial Conditions ... 5-1
5.5 Verification Limits ... 5-1
5.6 Input Connections ... 5-1
5.7 Verification Procedures ... 5-1
5.7.1 Volts Verification ... 5-2
5.7.2 Amps Verification ... 5-2
5.7.3 Ohms Verification ... 5-2

SECTION 6—THEORY OF OPERATION

6.1	Introduction	6-1
6.2	Power Supply	6-1
6.3	Model 6194 Electrometer Module	6-2
6.3.1	Description	6-2
6.3.2	Circuit Operation	6-2
6.4	Model 6193 IEEE-488 Interface Board	6-5
6.4.1	Description	6-5
6.4.2	Circuit Operation	6-5
6.5	Processor (CPU) Board	6-6
6.5.1	Description	6-6
6.5.2	Circuit Operation	6-6
6.6	Isolator Board	6-9
6.6.1	Description	6-9
6.6.2	Circuit Operation	6-9
6.7	Display/Keyboard	6-11
6.7.1	Description	6-11
6.7.2	Circuit Operation	6-11
6.8	A/D Board	6-11
6.8.1	Description	6-11
6.8.2	Circuit Description	6-11
6.9	Filter/Multiplexer Board	6-13

SECTION 7—MAINTENANCE

7.1	Introduction	7-1
7.2	Line Voltage Selection	7-1
7.3	Fuse Replacement	7-2
7.4	Internal Programming	7-2
7.4.1	Beeper Programming	7-3
7.4.2	Reading Rate Selection	7-3
7.4.3	External Trigger Mode	7-3
7.4.4	Line Frequency Selection	7-3
7.5	Calibration	7-4
7.5.1	Environment Conditions	7-4
7.5.2	Recommended Test Equipment	7-4
7.5.3	Calibration Cover Installation	7-5
7.5.4	Calibration Sequence	7-5
7.5.5	Calibration Procedure	7-5
7.5.6	Shielded Fixture Construction	7-9
7.6	Special Handling of Static-Sensitive Devices	7-10
7.7	Handling And Cleaning Precautions	7-10
7.8	Disassembly Instructions	7-11
7.9	Troubleshooting	7-14
7.9.1	Recommended Test Equipment	7-14
7.9.2	Power-Up Self Test	7-14
7.9.3	Prepower-Up Visual Checks	7-15
7.9.4	Power Supply Checks	7-15
7.9.5	CPU Board Checks	7-16
7.9.6	Isolator Board Checks	7-16
7.9.7	Filter Mux Board Checks	7-17
7.9.8	A/D Board Checks	7-17
7.9.9	Electrometer Board Checks	7-18
7.10	Fan Filter Cleaning	7-18

SECTION 8—REPLACEABLE PARTS

8.1	Introduction	8-1
8.2	Parts List	8-1
8.3	Ordering Information	8-1
8.4	Factory Service	8-1
8.5	Schematic Diagrams And Component Location Drawings	8-1

LIST OF ILLUSTRATIONS

SECTION 2

2-1 Model 619 Front Panel 2-5
2-2 Model 619 Rear Panel 2-5
2-3 Input Connector Configuration 2-8
2-4 Voltage Measurement Connections 2-9
2-5 Meter Loading Considerations 2-9
2-6 Current Measurements (2nA-20mA Ranges) 2-10
2-7 Voltage Burden Considerations 2-11
2-8 Range Connections 2-12
2-9 Common Input Current Range 2-13
2-10 Resistance Measurement Connections 2-14
2-11 Leakage Model for Dual Channel Operation 2-16
2-12 Typical Analog Output Connections 2-17
2-13 Unguarded Circuit 2-18
2-14 Guarded Circuit 2-19
2-15 Model 619 Guarded Adapter 2-19
2-16 Typical Guarded Connections 2-20
2-17 Model 6194 Electrometer Input Circuit 2-20
2-18 Shielded Fixture Constructions 2-22
2-19 Charge Measurement 2-23
2-20 Logarithmic Current Measurement 2-23
2-21 Non-Decade Current Gain Measurement 2-24
2-22 Equivalent Input Impedance with Zero Check Enable 2-25
2-23 External Trigger Pulse Specifications 2-26
2-24 Meter Complete Pulse Specification 2-27
2-25 External Triggering Example 2-27
2-26 Multiple Ground Points Create a Ground Loop 2-28
2-27 Eliminating Ground Loops 2-28
2-28 Leakage Resistance Effects 2-29
2-29 Input Capacitance Effects 2-30

SECTION 3

3-1 IEEE Bus Configuration 3-2
3-2 IEEE-488 Handshake Sequence 3-3
3-3 Command Groups 3-6
3-4 System Types 3-8
3-5 IEEE-488 Connector 3-8
3-6 IEEE-488 Connections 3-8
3-7 Locations for IEEE-488 Connector and Programming Switches 3-9
3-8 Contact Assignments 3-9
3-9 Binary Data Format (D1 Mode) 3-24
3-10 Machine Status Format 3-36

SECTION 4

4-1 Isolation Resistance Measurement (Unguarded) 4-2
4-2 Guarded Isolation Resistance Measurements 4-3
4-3 Isolation Resistance Measurement Using External Voltage Source 4-4
4-4 Measuring High Impedance Gate Source Voltage 4-5
4-5 Leakage Current Measurement 4-6

4-6 Diode Characterization 4-7
4-7 Diode Curves 4-8
4-8 Capacitor Leakage Tests 4-9
4-9 Capacitor Measurement 4-9
4-10 Faraday Cup Construction 4-11

SECTION 5

5-1 Resistance Source Shielding 5-3
5-2 Measuring Resistance Sources Using Model 6191 Guarded Input Adapter 5-3

SECTION 6

6-1 Model 619 Block Diagram 6-1
6-2 Electrometer Module Block Diagram 6-3
6-3 Data Bus Buffer 6-7
6-4 Memory Map 6-8

SECTION 7

7-1 Line Voltage Selection Switches 7-1
7-2 Isolation Board and Switches 7-3
7-3 Calibration Cover and Adjustment Locations 7-5
7-4 200mV Reference Calibration Configuration 7-6
7-5 2V Reference Configuration and Multiplier Calibration 7-7
7-6 2μA, 200μA and 20mA Range Calibration Configuration 7-7
7-7 20nA Range Calibration Configuration 7-8
7-8 20kΩ Range Calibration Configuration 7-8
7-9 20GΩ Range Calibration Configuration 7-9
7-10 Shielded Fixture Construction (for Calibrating 20GΩ Range) 7-10
7-11 Model 619 Exploded View (sheet 1 of 2) 7-12
7-11 Model 619 Exploded View (sheet 2 of 2) 7-13
7-12 Output of AT1 7-17
7-13 Output of AT2 and AT3 7-17
7-14 Output of AT4 7-17
7-15 Integrator Output 7-18

SECTION 8

8-1 Display Board, Component Location Drawing, Drawing Number 32003 8-4
8-2 Display Board, Schematic Diagram, Drawing Number 30515 8-5
8-3 Power Supply Board, Component Location Drawing, Drawing Number 32004 8-8
8-4 Power Supply Board, Schematic Diagram, Drawing Number 30516 8-9
8-5 IEEE Interface Board, Component Location Drawing, Drawing Number 30329 8-12
8-6 IEEE Interface Board, Schematic Diagram, Drawing Number 30518 8-13
8-7 Mother Board, Component Location Drawing, Drawing Number 30411 8-18
8-8 Mother Board, Schematic Diagram, Drawing Number 30517 8-22
8-9 Processor Board, Component Location Drawing, Drawing Number 32005 8-22
8-10 Processor Board, Schematic Diagram, Drawing Number 30519 8-23
8-11 Isolator Board, Component Location Drawing Drawing Number 32006 8-28
8-12 Isolator Board, Schematic Diagram, Drawing Number 30520 8-29
8-13 A/D Converter Board, Component Location Drawing, Drawing Number 30395 8-34
8-14 A/D Converter Board, Schematic Diagram, Drawing Number 30395 8-35
8-15 Electrometer Module PC-522, Component Location Drawing, Drawing Number 30387 8-42
8-16 Electrometer Module PC-522, Schematic Diagram, Drawing Number 30387 8-43
8-17 Electrometer Module PC-523, Component Location Drawing, Drawing Number 30391 8-46
8-18 Electrometer Module PC-523, Schematic Diagram, Drawing Number 30523 8-47
8-19 Filter Mux Board, Component Location Diagram, Drawing Number 30352 8-52
8-20 Filter Mux Board, Schematic Diagram, Drawing Number 30524 8-53

LIST OF TABLES

SECTION 2

2-1 Front Panel Display Messages 2-3
2-2 Range Selection 2-7
2-3 Ohms Function Output Current Values 2-14
2-4 Full Scale Analog Output Values 2-18
2-5 C_{FB} Selection 2-24
2-6 Voltage and Percent Error For Various Time Constants 2-31

SECTION 3

3-1 IEEE-488 Bus Command Summary 3-4
3-2 Hexadecimal and Decimal Command Codes 3-5
3-3 Typical Addressed Command Sequence 3-7
3-4 Typical Device-Dependent Command Sequence 3-7
3-5 IEEE Contact Designations 3-9
3-6 Primary Address Settings 3-10
3-7 Secondary Addresses 3-11
3-8 Talk-Only Mode Data Formats 3-11
3-9 BASIC Statements Necessary to Send Bus Commands 3-12
3-10 IEEE Command Groups 3-13
3-11 General Bus Commands and Associated BASIC Statements 3-14
3-12 Default Conditions 3-16
3-13 Front Panel Error Messages Associated with IEEE-488 Operation 3-19
3-14 Device-Dependent Command Summary 3-20
3-15 Range Command Summary 3-22
3-16 ASCII Data Formats (D0) 3-24
3-17 Equivalent Decimal Values for Binary Mantissa 3-25
3-18 Equivalent Decimal Values for Binary Exponent 3-25
3-19 Reading Rate Modes 3-27
3-20 Status Byte Format 3-33
3-21 Data Terminators 3-35
3-22 Machine Status Byte Definitions 3-38
3-23 One Shot Times (Typical) in Milliseconds 3-39
3-24 Typical Trigger to First Byte Times when Changing Modes 3-40
3-25 Continuous Times (Typical) in Milliseconds 3-40

SECTION 4

4-1 Diode Currents 4-7

SECTION 5

5-1 Volts Verification Limits 5-2
5-2 Amps Verification Limits 5-2
5-3 Ohms Verification Limits 5-3

SECTION 6

6-1 Register Commands 6-6
6-2 Register Commands 6-7
6-3 Jumpers for PROM Selection 6-9
6-4 Register Commands 6-10
6-5 Analog Bus Connector Pin Assignments Valid for Channel A 6-14
6-6 Analog Bus Connector Pin Assignments Valid for Channel B 6-15
6-7 Electrometer Control 6-16
6-8 Control Data Bit Designation 6-17

SECTION 7

7-1 Line Voltage and Fuse Selection 7-2
7-2 Recommended Calibrated Equipment 7-4
7-3 Static Sensitive Devices 7-10
7-4 Recommended Troubleshooting Equipment 7-14
7-5 Power-Up Checks 7-14
7-6 Digital Supply Checks 7-15
7-7 Analog Supply Checks 7-15
7-8 CPU Board Checks 7-16
7-9 Isolator Board Checks 7-16
7-10 Filter Mux Board Checks 7-18
7-11 Analog to Digital Converter Board (A/D) Checks 7-18
7-12 Electrometer Board Checks 7-19
7-13 Analog Self Test 7-19

SECTION 8

8-1 Display Board, Parts List 8-2
8-2 Power Supply, Parts List 8-7
8-3 IEEE Interface, Parts List 8-11
8-4 CPU Board, Parts List 8-15
8-5 Isolator Board, Parts List 8-25
8-6 A/D Converter, Parts List 8-31
8-7 Electrometer Module PC-523 and PC-522 Parts List 8-37
8-8 Filter Mux Board, Parts List 8-49
8-9 Fan Assembly, Parts List .....
8-10 Mechanical Parts .....

SECTION 1
GENERAL INFORMATION

1.1 INTRODUCTION

The Keithley Model 619 Electrometer/Multimeter is a microprocessor-based instrument with broad measurement range. In the amps mode, the Model 619 can resolve currents as low as 10fA (10^{-14}A) and measure as high as 2A. In volts, the instrument has 1μV resolution and is capable of voltage measurements up to 200V. In ohms, resistance measurements with 0.01Ω resolution and as high as 2TΩ can be made. With the optional Model 6193 IEEE-488 interface installed, the instrument can be controlled and programmed from a computer.

1.2 FEATURES

Important Model 619 features include:

- Selectable 4½ digit or 5½ digit display resolution.
- Autoranging for most measuring functions.
- Optional Model 6193 IEEE-488 interface that allows the instrument to be controlled from a computer.
- Dual channel capability with the optional second Model 6194 Electrometer Module installed. Ratio and difference modes are available when the instrument is equipped with two electrometer modules.
- Zero correct and zero check modes allow the user to easily cancel any internal offsets.
- Suppression modes allow baseline values to be stored and subtracted from subsequent readings.
- Guarded operation with the optional Model 6191 Guarded Input Adapter reduces the effects of input capacitance and leakage resistance.

1.3 WARRANTY INFORMATION

Warranty information for your Model 619 may be found inside the front cover of this manual. Should you need to use the warranty, contact your Keithley representative or the factory for information on obtaining warranty service. Keithley Instruments, Inc. maintains service facilities in the United States, West Germany, Great Britain, France, the Netherlands, Switzerland and Austria. Information concerning the operation, application or service of your instrument may be obtained from the applications engineer at any of these locations.

1.4 MANUAL ADDENDA

Information concerning improvements or changes to the instrument which occur after the printing of this manual will be found on an addendum sheet included with this manual. Please be sure that you read this information before attempting to operate or service your instrument.

1.5 SAFETY SYMBOLS AND TERMS

The following safety symbols and terms are used in this manual and found on the instrument.

The ⚠ symbol on the instrument indicates that the user should refer to the operating instructions in this manual for further details.

The **WARNING** heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

1.6 SPECIFICATIONS

Detailed Model 619 specifications are located at the front of this manual. In addition, the following paragraphs provide clarification of many of those specifications.

1.6.1 Volts Specifications

Accuracy Specification Assume: With input offset by zero correct function after warm-up, and every 24 hours thereafter. Correct whenever $\|dT_a\| > 1°C$. Spec exclusive of noise. Specified temperatures are packaged ambient. With greater than one line period integration.

Temperature Coefficient Specifications Assume: With source resistance $<100M\Omega$.

NMRR Specifications Assume: >55dB valid with DC inputs up 90% of ±full scale. Rating based on one digit injection on

2V through 200V ranges and four digits injection on 200mV range. At 50 and 60Hz, maximum reading rate, with one line-period integration. Filtering adds 25dB.

CMRR Specifications Assume: >100dB valid for 200mV and 2V ranges. Rating decreases to 80dB for 20V range and 60dB for 200V range. At DC, 50 and 60Hz with 1kΩ unbalance, maximum reading rate, one line-period integration.

Analog Settling Time Specifications Assume: Exclusive of input noise, with less than 1mA of total resistive and dV/dT capacitive analog load (maximum capacitance 5000pf). Exclusive of source response time and A/D conversion time. Refer to Model 619 Systems Use Specifications for digitization times.

Input Noise: (20μVp-p Assuming): With source resistance <100MΩ. Over one minute, unfiltered, self-generated.

1.6.2 Amps Specifications

External Feedback Specifications: Range: External Feedback (9). Maximum Reading: 1.9999(V). Accuracy: ±year, 23°C, ±5°C, ±(%rdg + digits): 0.01% + 1d. Temperature Coefficient: 0-18°C and 28-50°C, ±(%rdg + digits)/°C: 0.002% + 0.3d.

External feedback range requires user supplied feedback element for current to voltage conversion (resistor), charge to voltage conversion (capacitor), etc. Accuracy and temperature coefficient specifications are in addition to (but not including) that of feedback element. Feedback element is connected from the analog output to the module input. NMRR, noise and analog settling times will be a function of the feedback element. Displayed reading is the voltage across the external feedback element.

Accuracy Specifications Assume: With input offset corrected by zero correct function after warmup and every 24 hours thereafter. Correct whenever dT_a >1°C. Spec exclusive of noise. Specified temperatures are packaged ambient, with greater than one line-period integration.

NMRR Specifications Assume: Valid with DC inputs up to 90% of ±full scale. At 50 and 60Hz, maximum reading rate, one line-period integration. Filtering adds 25dB.

Analog Settling Time Specifications Assume: With less than 1mA of total resistive and dV/dT capacitive analog output load (maximum capacitance 5000pF). Exclusive of source response time and A/D conversion time. Refer to Model 619 System Use Specifications for digitization times.

Input Noise: 2μA: 5d; 20μA: 0.5d; 200μA, 20μA, 2μA, 2A: 2d; 2μA, 200μA, 20μA: 0.3d. External feedback: 0.3d. Digits, peak to peak, over one minute, unfiltered, self-generated, 4½ digit readout.

Input Voltage Drop: Whenever a series connected voltage source and resistor are used to calibrate, or verify the Model 619 amps range, the effect of the input voltage drop must be taken into account. From the specifications the maximum value of 1mV will constitute an uncertainty in the effective accuracy of the voltage source. Maintaining this source at voltage levels >1.9V will reduce this uncertainty to <0.05%.

1.6.3 Ohms Specifications

Accuracy Specifications Assume: With input offset corrected by zero correct function after warm-up and every 24 hours thereafter. Correct whenever dT_a >1°C. Spec exclusive of noise. Specified temperatures are packaged ambient, with greater than one line-period integrations. External voltage sources < 50V.

1.6.4 General Specifications

Maximum Allowable Input: Input overload source must be noninductive with a capacitive component less than 5000pF.

Isolation: Input LO to power line ground, >100MΩ shunted by approximately 750pF. A/D converter common to electrometer module input, <0.5pF.

Input Stability: Stable with <5000pF input to common and/or guard (analog output in volts or ohms) and analog output to input common.

Ranging: Manual or automatic in talk-only mode. Manual in addressable mode. Range exponents are multiples of three (0, ±3, ±6, ±9, ±12, ±15, ±18).

Weight: Model 6194 Electrometer: 1lb. 12oz. (0.81kg), Model 6193 IEEE-488 Interface: 6.5oz (0.18kg), Model 6191 Guarded Adapter: 5oz. (0.18kg).

Maximum Allowable Common Mode Slew Rate: 10^9V/sec, with no loss of data or commands across isolator.

Analog Output Characterisitics:
Voltage: $V_{out} = V_s \pm 1mV$
Current: $V_{out} = -(I_s \times R_{FEEDBACK}) \pm 1mV = 200mV$ F.S. on 2nA, 200nA, 20μA and 2mA ranges.
2V F.S. on 20nA, 2μA, 200μA and 20mA ranges.
Resistance: $V_{out} = R_S \times I_{SENSE} \pm 1mV$ (Output same as voltage across unknown).
Output Resistance: 1kΩ
Maximum Allowable Output Current: 1mA
Maximum Allowable Input Voltage (externally applied with respect to analog output common): 20V peak.

1.7 USING THIS INSTRUCTION MANUAL

This manual contains all the information necessary for you to operate and service your Model 619 Electrometer/Multimeter. The manual is divided into the following sections:

- Section 1 contains general information about your instrument including that necessary to unpack the instrument and get it operating as quickly as possible.
- Section 2 contains detailed operating information on how to use the front panel controls, make connections, and basic measuring techniques for each of the available measuring functions.
- Information necessary to connect the Model 619 to the IEEE-488 bus and program operating modes and functions from a controller is contained in Section 3. The optional Model 6193 IEEE-488 interface must be installed.
- Typical applications for the Model 619 are included in Section 4. At least one application for each of the measuring functions is included in this section.
- Performance verification procedures for the instrument may be found in Section 5. This information will be helpful if you wish to verify that the instrument is operating in compliance with its stated specifications.
- Section 6 contains a complete description of operating theory for the Model 619.
- Should your instrument ever require servicing, refer to the information located in Section 7. This section contains information on fuse replacement, line voltage selection, calibration, and troubleshooting.
- Replacement parts may be ordered by using the information contained in Section 8. Parts lists as well as schematic diagrams and component layouts are located in this section.

1.8 UNPACKING AND INSPECTION

The Model 619 Electrometer/Multimeter was carefully inspected before shipment. Upon receiving the instrument, carefully unpack all items from the shipping carton and check for any obvious signs of physical damage that might have occurred during shipment. Report any damage to the shipping agent at once. Retain the original packing material in case reshipment becomes necessary.

The following items are included with every Model 619 shipment:

Model 619 Electrometer/Multimeter
One Model 6194 Electrometer Module
Model 619 Instruction Manual
Model 6011 Triaxial Input Cable
Additional accessories as ordered.

If an additional instruction manual is required, order the manual package (Keithley Part Number 30194-00). The manual package includes an instruction manual and all pertinent addenda.

1.9 GETTING STARTED

The Model 619 Electrometer/Multimeter is a highly sophisticated instrument with many capabilities. Although there are a number of complex aspects about the instrument, you can use the following procedure to get your instrument up and running quickly. For more detailed information, you should consult the appropriate section of the manual.

1. Carefully unpack your instrument as described in paragraph 1.8.
2. Locate the power cord and plug it into the rear panel power jack. Plug the other end of the line cord into an appropriate power source. See Section 2 for more complete information.
3. Connect the Model 6011 triaxial cable to the rear panel input jack.
4. Press the front panel POWER switch to apply power to the instrument (check to see that rear panel POWER switch is ON). The instrument will power up the volts mode with zero check enabled. Thus, you could simply connect the Model 6011 red and black input leads to a voltage source and take a voltage reading at this point by disabling zero check. Remember that the Model 619 measures DC voltages up to 200V.
5. To change to a different function, simply press the desired function button. For example, to measure resistance, simply press the OHMS button.
6. Detailed information concerning Model 619 front panel operation may be found in Section 2. If you wish to control these functions over the IEEE-488 bus, consult Section 3 (the optional Model 6193 interface must be installed for IEEE-488 operation).

1.10 PREPARATION FOR USE

Once the instrument is unpacked, it must be connected to an appropriate power source as described below.

Line Power—The Model 619 is designed to operate from 90-125V or 180-250V power sources. The factory set range is marked on the rear panel of the instrument. Note that the line plug is designed to mate with the supplied 3-wire power cord.

CAUTION
Do not attempt to operate the instrument on a supply voltage outside the indicated range, or instrument damage might occur.

Line Voltage Selection—The operating voltage of the instrument is internally selectable. Refer to Section 7 for the procedure to change or verify the line voltage setting.

Line Frequency—The Model 619 may be operated from either 50 or 60Hz power sources. The operating frequency is internally switch selected.

IEEE-488 Primary Address (with optional Model 6193)—If the Model 619 is to be programmed over the IEEE-488 bus, it must be set to the correct primary address. The primary address is set to 6 at the factory, but it may be set to other values as described in Section 3.

1.11 REPACKING FOR SHIPMENT

Before shipping, the instrument should be carefully packed in its original packing material.

If the instrument is to be returned to Keithley Instruments for repair or calibration, include the following:

Write ATTENTION REPAIR DEPARTMENT on the shipping label.
Include the warranty status of the instrument.
Complete the service form at the back of this manual.

1.12 ACCESSORIES

The following accessories are available to enhance Model 619 capabilities.

Models 1019A and 1019S Rack Mounting Kits—The Model 1019A is a fixed stationary rack mounting kit to enable rack mounting of the Model 619. The Model 1019S is a similar rack mounting kit with a sliding mount configuration.

Model 6011 and 6011-10 Triaxial Cables—The Model 6011 is made up of three feet of triaxial cable that is terminated with a triax plug on one end and three alligator clips on the other end. The Model 6011-10 is a similar cable 10 feet in length. Note that the Model 6011 is supplied with the Model 619.

Model 6012 Triax to UHF Adapter—The Model 6012 allows the Model 619 to be used with accessories having UHF type connectors.

Model 6101A Shielded Test Lead—The Model 6101A is a straight through probe and shielded lead equipped with 0.8m (30″) of shielded low noise cable terminated by a Teflon-insulated UHF connector. The Model 6012 must be used to adapt the Model 6101A to the Model 619 triaxial input.

Model 6103C Voltage Divider Probe—The Model 6013C extends Model 619 voltage range to 30kV. The Model 6103C has a division ratio of 1000:1 with a nominal accuracy of 5%. The probe has an input resistance of $4.5 \times 10^{11}\Omega$ and is equipped with a UHF male plug. The Model 6012 adapter must be used to connect the Model 6103C to the Model 619.

Model 6104 Test Shield—The Model 6104 facilitates resistance, voltage or current measurements with either 2- or 3-terminal guarded connections at voltages up to 1200V. The Model 6104 provides excellent electrostatic shielding and high isolation resistance. Clips plug into banana jacks allowing custom connections. The Model 6104 has a BNC connector on one side and binding posts on the other. The Model 6147 adapter is required to connect the Model 6104 to the Model 619.

Model 6105 Resistivity Chamber—The Model 6105 is a guarded test fixture for measuring voltage and surface resistivities. The unit assures good electrostatic shielding and high insulation resistance. The complete system requires the use of an external high-voltage supply such as the Model 247 as well as the Model 619. Volume resistivity up to $10^{9}\Omega$/cm and surface resistivity up to $10^{18}\Omega$ can be measured in accordance with ASTM test procedures. Sheet samples 64 to 102mm (2½ × 4″) in diameter and up to 6.4mm (¼″) thickness can be accomodated. Excitation voltages up to 1000V may be used.

Model 6146 Triax Tee Adapter—The Model 6147 allows the simultaneous connection of two triaxial cables to the single triaxial input of the Model 619.

Model 6147 Triax to BNC Adapter—The Model 6147 allows the Model 619 input to be connected to accessories having BNC connectors.

Models 6171 and 6172 3-Lug-to-2 Lug Adapters—The Model 6171 is a 3 lug male-to-2 lug female triaxial adapter, while the Model 6172 is a 2 lug male-to-3 lug female triaxial adapter.

Model 6191 Guarded Adapter—The Model 6191 Adapter is intended for use with the Model 6194 Electrometer Module. It provides a convenient method to guard the input signal, thus minimizing the effects of input capacitance and leakage

resistance. The Model 6191 connects to the INPUT and ANALOG OUTPUT connectors on the Model 6194 and has a female triaxial connector for input signals. A switch allows easy selection of guarded or unguarded operation. In the guarded mode, effective cable capacitance is reduced to approximately 2pF.

Model 6193 IEEE-488 Interface—The Model 6193 installs within the Model 619 and allows the unit to be controlled over the IEEE-488 bus. The primary address of the unit and addressable/talk-only operation can be set by DIP switches located on the rear panel of the Model 619 when the interface is installed within the instrument.

Model 6194 Electrometer Module—The Model 6194 is the module supplied in channel A of the Model 619. A second Model 6194, installed in the channel B location, will allow dual-channel operation of the electrometer. The module has circuits to process volts, ohms and amps signals. These signals are converted into a 2V or 200mV level that is further processed by the A/D converter and filter/mux modules.

Model 6195 Maintenance Kit—The Model 6195 contains a calibration cover and extender cards for use when servicing the Model 619. The calibration cover is installed in place of the normal Model 619 top cover during calibration. It allows the instrument to reach normal internal operating temperature during calibration and has access holes for adjustments. The extender cards allow easy access to PC boards during troubleshooting.

Model 7008 IEEE-488 Cables—The Model 7008 cables are designed to connect the Model 619 to the IEEE-488 bus and are available in two similar versions. The Model 7008-3 is 0.9m (3 ft.) in length, while the Model 7008-6 is 1.8m (6 ft.) long. Each cable is terminated with a standard IEEE-488 connector on each end, and each connector is equipped with two metric screws.

Model 7023 Female Triaxial Connector—The Model 7023 is a chassis mount connector that mates with the Models 6011 and 7024 triaxial cables.

Model 7024 Triaxial Cables—The Model 7024 cables are similar units with male triaxial connectors on each end. The Model 7024-1 is 0.3m (1 ft.) in length, while the Models 7024-3 and 7024-10 are 0.9m (3 ft.) and 3.0m (10 ft.) long respectively. These cables may be used to connect the Model 619 signal input to other equipment having similar triaxial connections.

Model 8573 IEEE-488 Interface for the IBM PC—The Model 8573 allows the Model 619 to be connected to and controlled from the IBM PC via the IEEE-488 bus (the optional Model 6193 interface must be installed for IEEE-488 operation).

SECTION 2
OPERATION

2.1 INTRODUCTION

This section contains a complete description of Model 619 front panel operation. First front panel and rear panel functions are described in detail. Next a detailed procedure for using each of the measuring functions is presented. Finally, additional Model 619 operating modes such as analog output and guarding are discussed.

2.2 INTERNAL PROGRAMMING

Several Model 619 functions, including line frequency, reading rate, front panel triggering and beeper mode (enabled or disabled) are internally programmed by switches. Refer to Section 7 for details on programming these functions.

2.3 POWER UP PROCEDURES

Use the procedure below to connect the Model 619 to line power and apply power to the instrument.

1. Connect the female end of the power cord to the AC receptacle on the rear of the instrument. Connect the other end of the cord to a grounded AC outlet.

WARNING

The Model 619 is equipped with a 3-wire power cord that contains a separate ground wire and is designed to be used with grounded outlets. When proper connections are made, instrument chassis is connected to power line ground. Failure to use a grounded outlet may result in personal injury because of electric shock.

CAUTION

Be sure the power line voltage agrees with the indicated range on the rear panel of the instrument. Operation of the instrument on voltages outside this range may damage the instrument. If necessary, the operating voltage can be changed, as discussed in Section 7.

2. Check to see that the rear panel POWER switch is in the ON position.
3. Turn on the power by pressing the front panel POWER switch. The switch will be at the inner most position when power is applied.
4. When power is first applied, the beeper will sound for approximately two seconds, and all display segments and indicators will turn on. The programmed line frequency and software revision level will then be displayed briefly:

   F60 C-2

   In this example, the programmed line frequency is 60Hz, and the software revision level is C2. Note that the line frequency may be programmed to either 50 or 60Hz by an internal switch, as discussed in Section 7.

   The software revision level of your instrument should be recorded for reference should it become necessary to replace the internal ROM memory in the future.
5. Following the above display, the instrument will enter the operational mode. The CHANNEL A, ZERO CHECK, VOLTS and TRIGGER indicators will be on continuously, and the UPDATE indicator will be flashing. All other LEDs should be off when the instrument is first turned on.

2.4 POWER UP SELF TEST AND DISPLAY MESSAGES

During the power up cycle, the instrument performs a number of self tests to ensure that everything is operating properly. If a RAM error occurs, a blinking annunciator will indicate the defective RAM IC as follows:

CHANNEL A	U919
CHANNEL B	U920
RATIO A/B	U922
DIFFERENCE A-B	U923

In addition to the RAM test, the instrument will also perform a CRC test (Cyclic Redundancy Check) on the PROM memory. If this test fails, the CHANNEL A, CHANNEL B, RATIO A/B and DIFFERENCE A-B indicators will all blink.

During power up, several other checks are made on the system. If an error occurs, one of the messages in Table 2-1 will be displayed. Some of the messages such as "no ch-b" could occur during normal operation. Note that data sent over the internal isolator is continuously checked during normal operation. If after eight tries, data transfer is unsuccessful, the "Snd E" or "REC E" message will appear, depending on the type of error.

2.5 FRONT PANEL FAMILIARIZATION

The front panel layout of the Model 619 is shown in Figure 2-1. The front panel may be divided into two sections: control and display indicators. The following paragraphs give an overview of each of these items. More specific information on these functions may be found in the remainder of Section 2.

2.5.1 Controls

All front panel controls except POWER are momentary contact switches. When one of these buttons is pressed, an internal beeper will sound momentarily if the commanded operation is valid. Note that the beeper may be turned off by setting an internal switch. See Section 7 for details.

POWER—The power switch controls AC power to the instrument. When power is off, the switch is at its outer most position. When power is on, the switch will be in. These positions are marked on the front panel to the right of the switch. Note that an additional power switch is located on the rear panel; see paragraph 2.6.2 for details.

Channel Selection Group—These controls select the operational channel and the ratio and difference functions. Pressing CHANNEL A or CHANNEL B will select the appropriate channel. If no electrometer module is installed in the channel B location, pressing CHANNEL B will result in the "no ch-b" error message. Pressing RATIO A/B or DIFFERENCE A-B buttons will enter those modes, assuming that an electrometer module is installed in the channel B location. If the optional Model 6193 IEEE-488 interface is installed, the unit must be in the talk-only mode in order to use the ratio or difference functions. For a complete description of dual-channel operation, refer to paragraph 2.9. Note that all front panel buttons except CHANNEL A or CHANNEL B will be locked out when in the ratio or difference modes.

Function Selector Group—The VOLTS, AMPS and OHMS buttons select the three basic measuring functions of the Model 619. Measurement procedures are discussed in paragraph 2.8.

Range Selection Group—The AUTO/MANUAL button toggles the instrument between the autoranging and manual ranging modes. While in autoranging, the instrument will select the best range to measure the applied signal. Note that autoranging is not available in the 2A range.

The UPRANGE and DOWNRANGE buttons move the instrument up range or down range, respectively. Each time the button is pressed, the instrument will move one range. Pressing one of these buttons will also cancel the autorange mode if presently selected.

ZERO CHECK and ZERO CORRECT—These two buttons work together to cancel any internal offsets. The zero check mode must be enabled when enabling zero correct, or a "Corr I1" message will be displayed. Note that zero check cannot be used in the 2A range. For more information on these modes, refer to paragraph 2.12.

BASELINE STORE and BASELINE SUPPRESSION—These two buttons function together to allow storage of a baseline value to be subtracted from subsequent readings. See paragraph 2.13 for complete details.

FILTER—Additional filtering of the input signal may be added by pressing this button. Paragraph 2.14 discusses filtering in more detail.

RESOLUTION—The Model 619 front panel display may be operated in either the 4½ or 5½ digit modes. Pressing RESOLUTION will toggle the display between these two modes. See paragraph 2.15 for more information on using the RESOLUTION button.

2.5.2 Display and Indicators

The operation of the 4½ or 5½ digit display and indicators is discussed below.

Display—The Model 619 display is made up of a 4½ or 5½ digit signed mantissa and a 2-digit signed exponent. (4½ or 5½ digits are selected with the RESOLUTION button). With negative input signals, a leading minus sign will appear in the mantissa (plus is implied by the absence of a sign in the mantissa). The exponent will increment in steps of 3; ±0, ±3, ±6, ±9 and so on. The exponent will always show the appropriate sign (+ or −).

In addition to the normal readings (the rate is indicated by the UPDATE indicator), the display also shows a number of messages, as shown in Table 2-1. For example, under overload conditions, the display will show the "OFLO" message. If a negative overflow value is applied, a leading minus sign will appear in the display mantissa as well.

Display Indicators—Many of the display indicators show when basic operating modes are selected. For example, the CHANNEL A and CHANNEL B indicators show which chan-

Table 2-1. Front Panel Display Messages

Message	Interpretation
OFLO	Reading overload.
no CH A	Channel A module not present or malfunctioning.
no ch b	Channel B module not present or malfunctioning.
Snd E	Isolator transmitted data in error.
REC E	Isolator received data in error.
no A-d	A/D converter or filter/mux not present or malfunctioning.
no ISO	Isolator not present or malfunctioning.
no 2AC	No zero check or 2A range.
Corr IL	No zero check with zero correct.
no Au	No autoranging allowed in this mode.
ISbS *	Invalid string with baseline store.
IddC *	Illegal Device-Dependent Command.
IddCO *	Illegal Device-Dependent Command Option.
no rn *	Attempt to program when not in remote.

*These messages are concerned with IEEE-488 operation. See Section 3.

nel is selected, while the VOLTS, AMPS and OHMS indicators show the measuring function for the selected channel. In a similar manner, the ZERO CHECK, SUPPRESSION, RANGE, FILTER and EXT FEEDBACK indicators show when those modes are in effect for the selected channel.

The TRIGGER and UPDATE indicators show the trigger status of the instrument. The TRIGGER indicator shows when the instrument is being triggered. If the unit is in a continuous trigger mode, the indicator will appear to be on continuously. The UPDATE indicator shows when the display is being updated, as you might expect. The update rate will depend on the selected resolution and rate mode, which is discussed in Section 3.

The REMOTE, LISTEN, TALK, SRQ, BINARY, TALK-ONLY and LLO indicators are operational only when using the Model 619 over the IEEE-488 bus through the optional Model 6193 interface. Refer to Section 3 for information on IEEE-488 operation.

2.5.3 Tilt Bail

The tilt bail, which is located on the bottom cover, allows the front panel to be elevated to a convenient viewing height. To extend the bail, simply rotate it out 90° from the bottom cover until it latched into place. To retract the bail, rotate it back against the bottom cover.

2.6 REAR PANEL FAMILIARIZATION

The following paragraphs give an overview of the rear panel of the Model 619. Refer to Figure 2-2.

2.6.1 Connectors and Terminals

AC Receptacle—Power is applied through the supplied power cord to the AC receptacle. Note that the supply voltage is marked adjacent to the receptacle.

EXTERNAL TRIGGER—This BNC connector can be used to apply trigger pulses from other instruments to trigger the instrument to take one or more readings, depending on the selected trigger mode.

ELECTROMETER COMPLETE—This BNC connector provides an output pulse when the Model 619 has completed a reading; it is useful for triggering other instrumentation.

IEEE-488 Connector (Model 6193 option only)—The IEEE-488 connector is used to connect the Model 619 to the IEEE-488 bus.

INPUT—The INPUT connector is a 2-lug female triaxial connector to be used for all electrometer input signals except the

2A range. Note that you should not confuse a triaxial connector with a BNC type (such as those used for the EXTERNAL TRIGGER and ELECTROMETER COMPLETE connections). Also, do not attempt to use 3-lug triaxial connectors on the INPUT connector; the Models 6171 and 6172 adapters are available to make the necessary conversion.

2 AMPS MAX INPUT—These banana jacks are used to apply input signals for the 2A range. Input polarity is marked adjacent to the jacks.

ANALOG OUTPUT—The ANALOG OUTPUT provides a guard output for voltage and resistance measurements. This output can also be used as an inverting output or with external feedback when measuring current. Refer to paragraph 2.10.

2.6.2 Switches

POWER—The rear panel POWER works in conjunction with the front panel POWER switch to control power to the instrument. Since the two switches are wired in series, both must be in the ON position in order to apply power to the unit.

ADDRESS (Model 6193 option only)—These DIP switches set the IEEE-488 primary address and talk-only/addressable mode when using the Model 619 over the IEEE-488 bus. Refer to Section 3.

2.6.3 Fuses

The line fuse, located next to the AC receptacle, protects the AC power line input. The 2 AMP fuse, located on the electrometer module, protects the 2A INPUT against current overloads. For procedures to replace these fuses, refer to Section 7.

2.7 FUNCTION AND RANGE SELECTION

2.7.1 Measuring Functions

The Model 619 has three measuring functions in standard configuration: volts, amps and ohms. In the volts mode, the instrument can resolve DC voltages as low as 1μV and measure as high as 200V. In amps, current changes as low as 10fA can be detected, while the measurement range extends to 2A. In ohms, the instrument can resolve resistances as low as 0.01Ω and measure as high as 2TΩ. Keep in mind that these resolution figures are for 5½ digit resolution; the resolution decreases by a factor of 10 when using 4½ digit resolution.

To select a measuring function, simply press the associated function button, VOLTS, AMPS or OHMS. When the button is pressed, the instrument will light the appropriate function indicator (VOLTS, AMPS or OHMS) and begin displaying readings for that function. Note that the function buttons are inoperative if the ratio or difference modes are enabled.

If the instrument is equipped with two channels, a separate measuring function can be selected for each channel. To do so, simply select the desired channel and then press the desired function button. Select the other channel and press the desired function if that function is different than the one being used on the other channel. Once the functions are selected, the instrument will automatically revert to the previously selected function when the channel is changed.

2.7.2 Range Selection

The Model 619 has two fundamental methods of range selection: autoranging and manual ranging. Each of these methods is discussed below.

Autoranging—To place the instrument in the autoranging mode, press the AUTO/MANUAL button. The AUTO RANGE indicator light will turn on, and the instrument will select the best range to measure the applied signal. Autoranging may be cancelled by pressing AUTO/MANUAL a second time, or by pressing the UPRANGE or DOWNRANGE buttons. Note that all three ranging buttons are inoperative if the ratio or difference modes are selected.

Autoranging is not available for the following modes:

1. External Feedback—External feedback must be manually selected with the UPRANGE button.
2. 2A range—The 2A range has a separate input and must be selected manually.
3. 2GΩ through 2TΩ Ranges—These ranges require measurements with long time constants.

If the AUTO/MANUAL button is pressed while the instrument is in one of the above modes, the "no Au" message will be displayed.

Manual Ranging—Manual range selection may be performed by pressing the UPRANGE or DOWRANGE buttons, as required. Each time the appropriate button is pressed, the instrument will move up or down one range, as the case may be. Pressing UPRANGE or DOWNRANGE will also cancel the autorange mode if presently selected. Once the instrument has reached the lowest or highest range for the selected function, pressing the button in question will have no further effect.

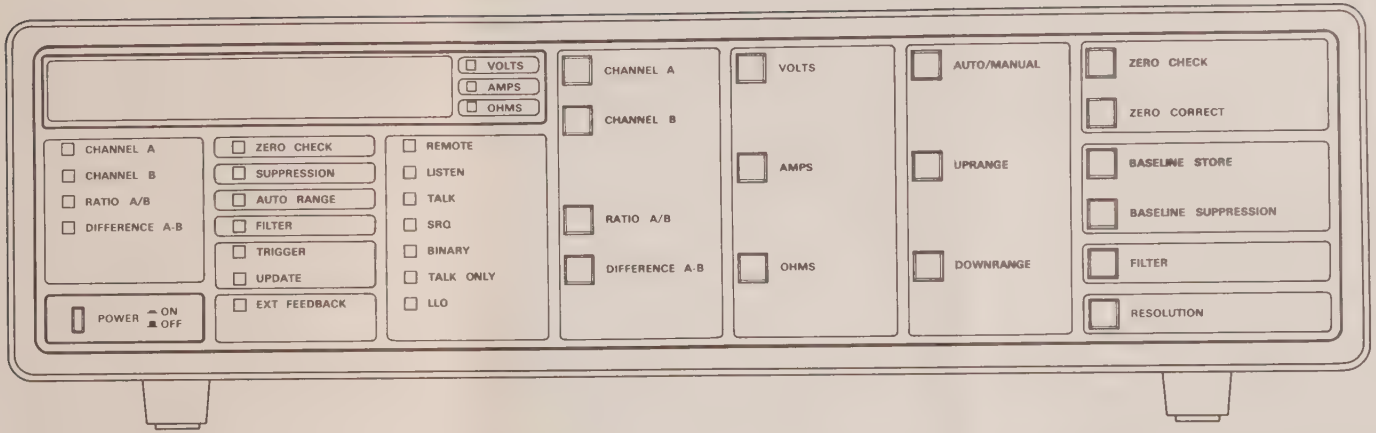


Figure 2-1. Model 619 Front Panel

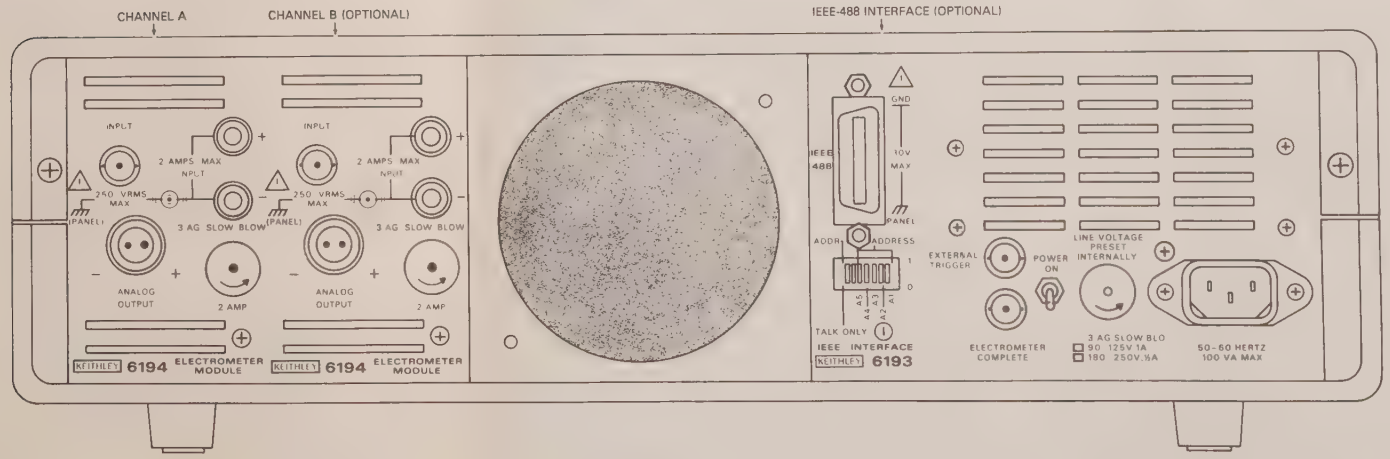


Figure 2-2. Model 619 Rear Panel

Range Selection Considerations: In most instances, it is best to use the lowest range possible without overranging the instrument. This will result in the best accuracy. Thus, it will be expedient to use the autoranging mode and let the instrument select the best range for the applied signal. In some cases, however, manual ranging may be desirable, or even required (as in the cases where autoranging is unavailable, as indicated above). One area where manual ranging would be appropriate is in the case of a rapidly changing input signal level that spans several ranges. If autoranging were used in this situation, the instrument may spend much of its time changing ranges, and be unable to process readings on a timely basis.

Although the Model 619 does not directly display the range in use, this mode can be determined by noting the position of the decimal point and the exponent. Table 2-2 summarizes ranges along with full scale values, including correct decimal point placement and exponent.

Table 2-2. Range Selection

Function	Range	Full Scale Reading*
Volts	200mV	199.999 – 3
	2 V	1.99999 + 0
	20mV	19.9999 + 0
	200 V	199.999 + 0
Amps	2 A	1.99999 – 9
	20 nA	19.9999 – 9
	200 nA	199.999 – 9
	2 μA	1.99999 – 6
	20 μA	19.9999 – 6
	200 μA	199.999 – 6
	2mA	1.99999 – 3
	20mA	19.9999 – 3
	2 A	1.99999 + 0
Ohms	2 kΩ	1.99999 + 3
	20 kΩ	19.9999 + 3
	200 kΩ	199.999 + 3
	2MΩ	1.99999 + 6
	20MΩ	19.9999 + 6
	200MΩ	199.999 + 6
	2GΩ	1.99999 + 9
	20GΩ	19.9999 + 9
	200GΩ	199.999 + 9
	2TΩ	1.99999 + 12

*Values for 5½ digit resolution shown.

The Model 619 measures the current as a feedback-type picoammeter on the 2nA-20mA ranges. During the measurement process, the input current is converted into a 200mV or 2V full scale output that is applied to the A/D converter for digitization. Those ranges that convert to 200mV (2nA, 200nA, 20μA and 2mA) will tend to have more noise than those ranges that convert the current to a 2V output (20nA, 2μA, 200μA and 20mA). Thus, one of these latter ranges would be more appropriate in cases where it is desired to keep noise to a minimum.

2.8 BASIC MEASUREMENT TECHNIQUES

The following paragraphs describe the basic procedures for making voltage, current and resistance measurements with the Model 619.

2.8.1 Warm Up Period

The Model 619 is useable immediately when it is first turned on. However, the instrument must be allowed to warm up for at least one hour to achieve rated accuracy.

2.8.2 Input Connections

Each rear panel INPUT connector is a Teflon-insulated receptacle intended for all input signals to the Model 619 except for the 2A range. As shown in Figure 2-3, the center terminal is high, the inner ring or shield is low, and the outer ring is connected to the instrument chassis ground.

NOTE

The input connector must be kept clean to maintain high input impedance.

The supplied Model 6011 input cable is designed to mate with the input connector. The other end of the Model 6011 is terminated with three alligator clips. Input high is color coded in red, input low is color coded black, and chassis ground is color coded in green.

NOTE

It is recommended that zero check be enabled when connecting or disconnecting input signals, except in cases where the lower (500kΩ) input resistance would have a detrimental effect in the signal source.

WARNING

The maximum common-mode input voltage (the voltage between input low and chassis ground) is 250V rms, DC to 60Hz sinewave. Exceeding this value may create a shock hazard.

CAUTION

The maximum voltage between input high and input low is 250V rms, DC to 60Hz sine wave (only the 2A range is fuse protected). Exceeding this value may cause damage to the instrument.

Connections for the 2A range are made using the red and black binding posts.

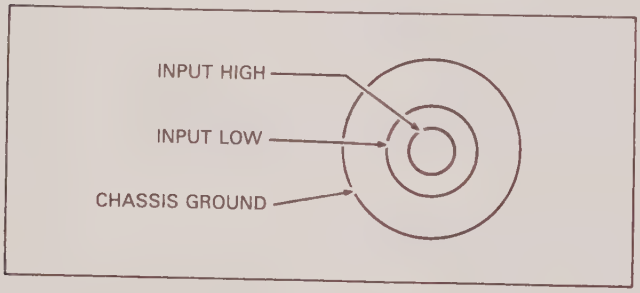


Figure 2-3. Input Connector Configuration

2.8.3 Making Voltage Measurements

The Model 619 can be used to measure voltages in the range of $\pm 1\mu V$ to $\pm 200V$. In principle, the instrument operates much like an ordinary DMM, but its special characteristics allow it to make measurements in cases where an ordinary DMM would be unable to perform well. In particular, the very high input resistance of $20T\Omega$ ($2 \times 10^{13}\Omega$) allows it to accurately measure voltage sources with high internal resistances. In contrast, an ordinary DMM may have an input resistance of only $10M\Omega$, resulting in inaccurate measurements because of instrument loading.

Use the procedure below to make voltage measurements.

1. Turn on instrument power and allow it to warm up for one hour to reach rated accuracy. Select the desired channel.
2. Check to see that the voltage function is selected by pressing the VOLTS button.
3. To achieve specified accuracy, especially on the lower ranges, it is recommended that you zero the instrument on the lowest range. To do so, first enable zero check and then press the ZERO CORRECT button. Correcting zero in the lowest range will correct all ranges because of internal scaling. Do not use autoranging when zero correcting the instrument.

NOTE

The input circuit configuration changes with zero check enabled. See paragraph 2.12.

4. Select the desired range, or use autoranging.
5. Connect the Model 6011 triaxial input cable or other similar cable to the rear panel INPUT jack of the desired channel. For sources with high output resistance, the cable should be kept as short as possible to minimize cable capacitance.
6. If response time and leakage resistance are considerations, place the instrument in the guarded mode as described in paragraph 2.10.
7. Connect the other end of the cable to the voltage to be measured, as shown in Figure 2-4. Disable zero check.
8. The reading may be obtained directly from the display.

Voltage Measurement Considerations: Two primary considerations come to mind when making voltage measurements, especially for voltage sources with high output resistances. For one thing, the loading effects of the measuring instrument come into play at the high resistance levels involved. Secondly, the distributed capacitance of the source, the input cable, and the input circuit of the instrument itself come into play when making the measurements.

To see how meter loading can affect accuracy, refer to Figure 2-5. In this figure, a voltage source E_S, with an output R_S is connected to the input of the electrometer, which has an input resistance represented by R_{IN}. The percent error due to loading can be calculated as follows:

$$\%ERROR = \frac{100R_S}{R_S + R_{IN}}$$

Thus, to keep the error under 0.1%, the input resistance must be about 1000 times the value of the source resistance, R.

At very high resistance levels, the very large time constants created by even a minimal amount of capacitance can slow down response time considerably. For example, measuring a source with an internal resistance of $100G\Omega$ would result in an RC time constant of one second when measured through a cable with a nominal capacitance of 10pF. If 1% accuracy is required, a single measurement would require at least five seconds.

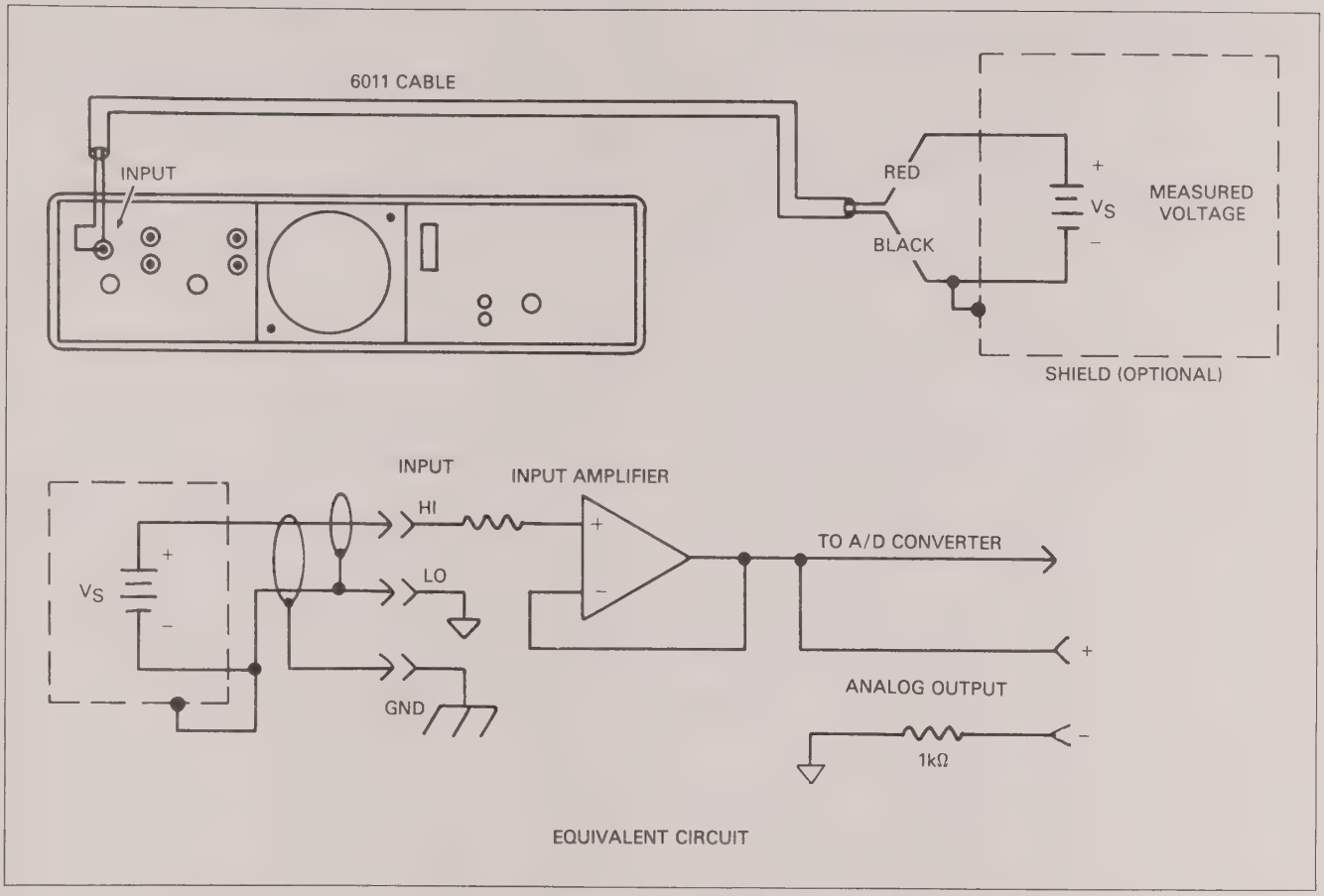


Figure 2-4. Voltage Measurement Connections

Basically, there are two ways to minimize this problem: (1) keep the input cable as short as possible, and (2) use guarding. With the first method, there is a limit as to how short the cable can be. Using guarding can reduce these effects substantially. See paragraph 2.10.2

At low signal levels, noise may affect accuracy. Shielding of the unknown voltage can reduce noise effects substantially. When using shielding, the shield should be connected to input low.

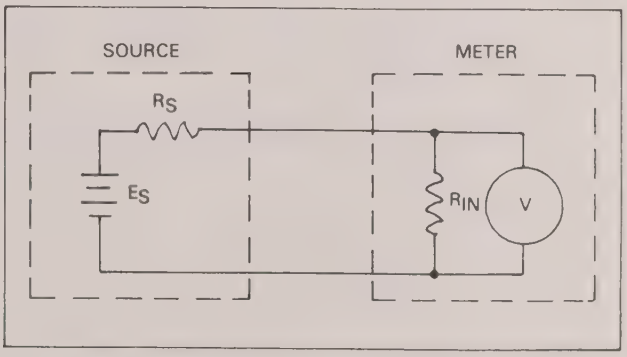


Figure 2-5. Meter Loading Considerations

2.8.4 Making Current Measurements (2nA-20mA Ranges)

The Model 619 can resolve current as low as 10fA (10^{-14}A), and measure as high as 2A on nine ranges. The Model 619 exhibits low input voltage burden and low input offset current. The low voltage burden is achieved because the Model 619 measures current on the 2nA-20mA ranges as a feedback type picoammeter, rather than the shunt method used by many DMMs.

NOTE

Safe operation and good measurement practice dictates the use of an external resistor when necessary to limit currents to less than 30mA when using the 2nA-20mA ranges.

To measure current with the Model 619, use the following procedure.

1. Turn on the power and allow the instrument to warm up for at least one hour to obtain rated accuracy. Select the desired channel.
2. Select the current mode by pressing the AMPS button on the front panel.
3. To achieve best accuracy, select the 2nA range (do not zero correct in autoranging), zero the instrument by enabling zero check and then pressing the ZERO CORRECT button. Select the desired range, or use autoranging if desired.
4. Connect the Model 6011 or other similar cable to the rear panel INPUT jack of the selected channel. Connect the other end of the circuit to be measured as shown in Figure 2-6. Shielding will be required for low-level measurements. Connect the shield to input low.
5. Disable zero check.
6. Read the current value directly from the display.

Current Measurement Considerations: At very low levels, noise currents generated in the cable or from other sources can affect measurements. Currents generated by triboelectric effects are a primary cause of noise currents generated in connecting cables. These currents are generated by charges created at the junction between a conductor and an insulator because of friction. Coaxial and triaxial cables are especially prone to such noise currents, which are generated by cable flexing. To minimize these effects, the cable should be tied down firmly to minimize any flexing. Also, special low-noise

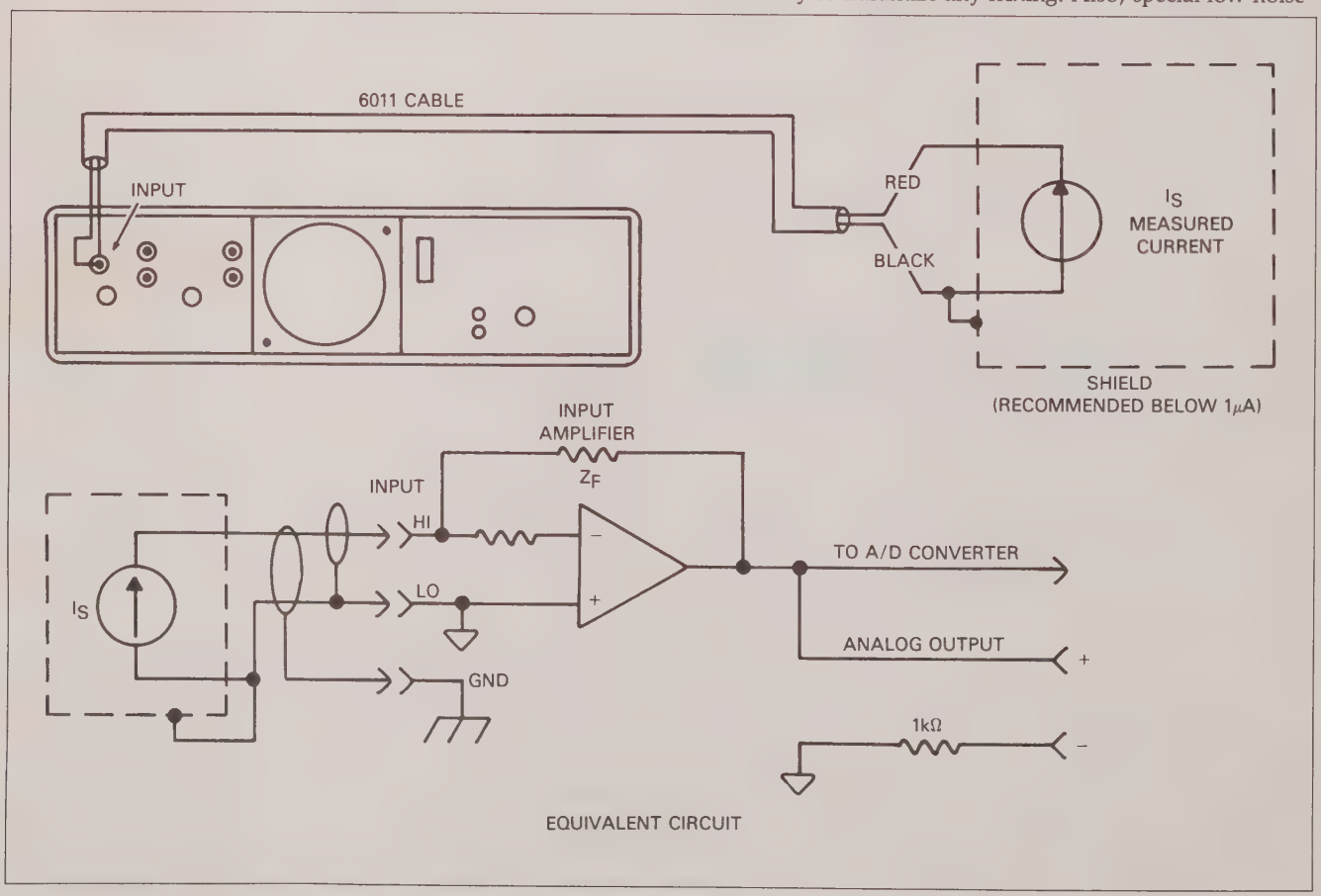


Figure 2-6. Current Measurements (2nA-20mA Ranges)

cable, constructed with graphite between the shield and insulator, is available to minimize these effects. However, even with low-noise cables, several tens of femtoamps of noise currents can be generated by cable movement.

Voltage burden is frequently a consideration when making current measurements. Ideally, the input voltage burden should be zero in order for the instrument to have absolutely no effects on the circuit it is measuring. If the voltage burden is too high, its effect can degrade measurement accuracy considerably.

To see how voltage burden can upset measurement accuracy, refer to Figure 2-7. A source, represented by E_S with an output resistance R_S is shown connected to the input of a picoammeter. The voltage burden is represented by a constant voltage source at the input as E_{IN}. If E_{IN} were zero, the current as seen by the meter would simply be:

$$I = \frac{E_S}{R_S}$$

However, if E_{IN} has a non-zero value, the current now becomes:

$$I = \frac{E_S - E_{IN}}{R_S}$$

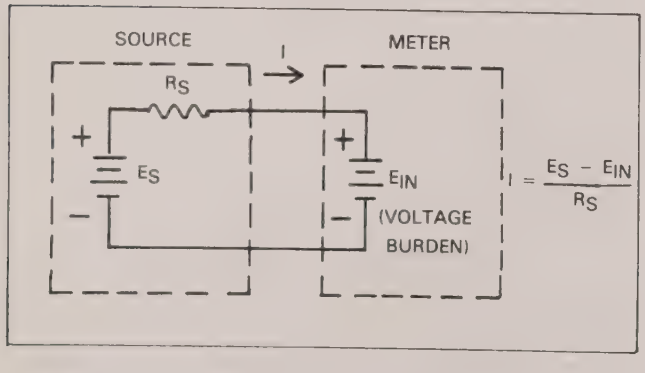


Figure 2-7. Voltage Burden Considerations

2.8.5 Current Measurements (2A Range)

Input signals for the 2A range are applied through a separate set of banana jacks. On this range, the Model 619 measures current as a shunt type ammeter rather than by the feedback method employed with the 2nA through 20mA ranges. The 2A input circuit is fused to protect the instrument from excessive currents. To measure currents on the 2A range, proceed as follows:

1. Turn on the power and allow the instrument to warm up for one hour to achieve rated accuracy.
2. Select the desired channel with the CHANNEL A or CHANNEL B pushbutton, as required.
3. Using the UPRANGE button, select the 2A range manually (no autoranging is available with the 2A range). An easy method that can be used to select the 2A range is to press the UPRANGE button repeatedly until the EXT FEEDBACK indicator turns on and then press the DOWNRANGE button once to select the 2A range.
4. Connect the current to be measured to the instrument as shown in Figure 2-8.

CAUTION

Maximum input current is 2A. Exceeding this value will cause the protection fuse to blow.

5. Read the current directly from the display.

NOTES:

1. Since no autoranging is available on the 2A range, pressing AUTO/MANUAL while on this range will result in the "no Au" message.
2. Neither zero check nor zero correct are available on the 2A range. Pressing ZERO CHECK while on this range will result in the "no 2A C" error message. Pressing ZERO CORRECT will result in the "Corr II" message because zero check cannot be enabled.

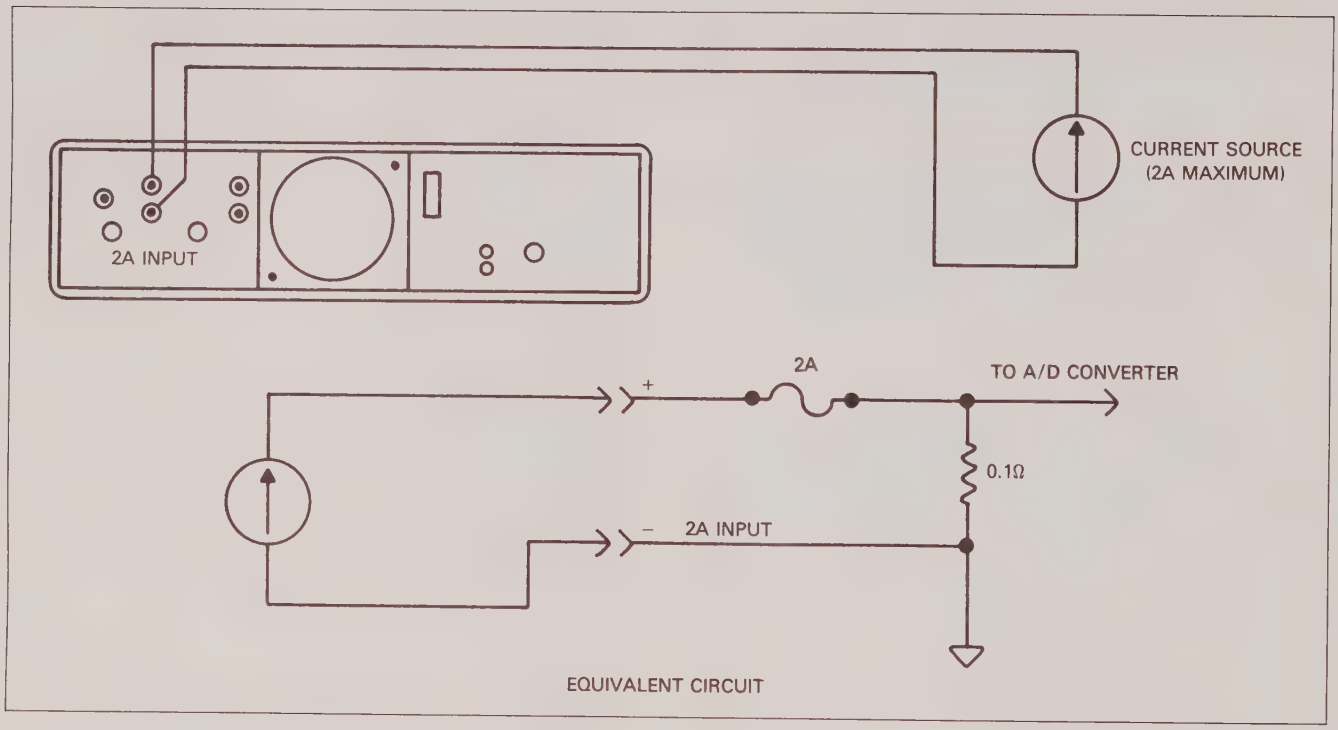


Figure 2-8. Range Connections

2.8.6 Common Input for the Current Ranges

Current inputs for the 2nA-20mA range are applied to the triaxial INPUT connector, while the input to the 2A range is applied through separate banana jacks. In some cases, it may be desirable to apply all signals to a single input, regardless of amplitude.

The circuit shown in Figure 2-9 can be used to modify the Model 619 for common current input. A single triaxial connector is used for all inputs, and a relay is used to switch to the 2A range. A separate 5V control voltage must be used to switch the relay. Any additional leakage current introduced by the relay can be nulled by using the BASELINE STORE/BASELINE SUPPRESSION buttons.

To minimize noise pickup, the entire circuit should be mounted in a shielded enclosure.

WARNING

If high common mode voltage is to be used, the entire circuit should be enclosed in a shield that is connected to chassis ground in order to prevent a possible shock hazard.

2.8.7 Resistance Measurements

The Model 619 can resolve resistances as low as 0.01Ω and measure as high as 2TΩ.

To measure resistance with the Model 619, use the following procedure:

1. Turn on the power and allow a one-hour warm-up period for rated accuracy. Select the desired channel.
2. Press the OHMS button to place the instrument in the correct mode.
3. For maximum accuracy, place the instrument on the 2kΩ range and zero the instrument by enabling zero check and then pressing the ZERO CORRECT button. Do not zero correct in the autorange mode.
4. Select the desired range, or use autoranging, if desired. Note that autoranging is not available on the 2GΩ-2TΩ ranges.
5. Connect the Model 6011 or similar cable to the INPUT jack for the selected channel. Keep the cable as short as possible to minimize the effects of cable capacitance. Connect the other end of the cable to the resistance to be measured, as shown in Figure 2-10. For measurements above 1GΩ, it is recommended that you use guarded connections, as described in paragraph 2.10.2.

6. Disable zero check.
7. Take the reading from the display.

Resistance Measurement Considerations: When measuring high resistance values, there are two primary factors that can affect measurement accuracy and speed. Any leakage resistance in the connecting cable or test fixture can decrease the actual resistance seen by the instrument. Also, capacitance of the cable or input can slow down the response time considerably.

These two problems can be minimized by using guarding, especially when measuring resistances above 1GΩ. Guarding is further discussed in paragraph 2.10.2. Noise pickup can also be a problem, in which case, the resistor must be shielded. Connect the shield to input low.

When measuring low resistances, lead resistance can be a consideration. To null the effects of lead resistance, connect the input leads together (red and black, if using the Model 6011 cable) and disable zero check. With the instrument on the 2kΩ range, press the BASELINE STORE button. Now press BASELINE SUPPRESSION to null out any lead resistance.

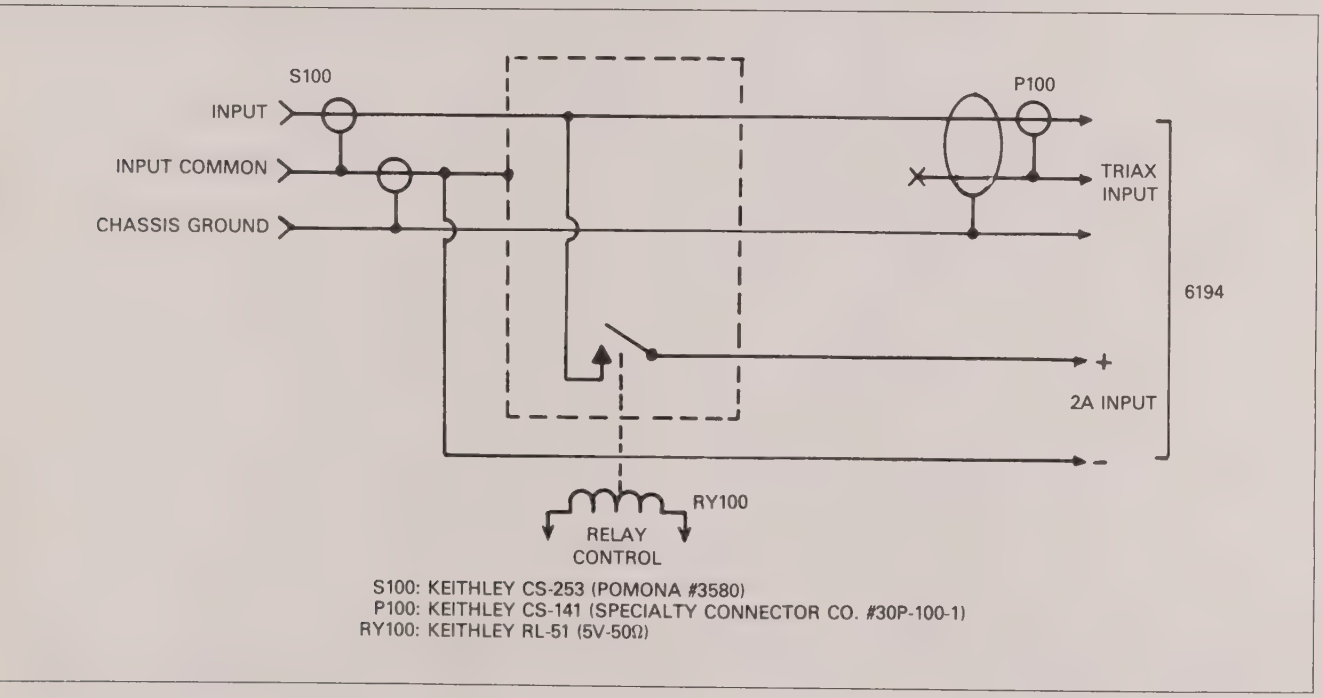


Figure 2-9. Common Input Current Range

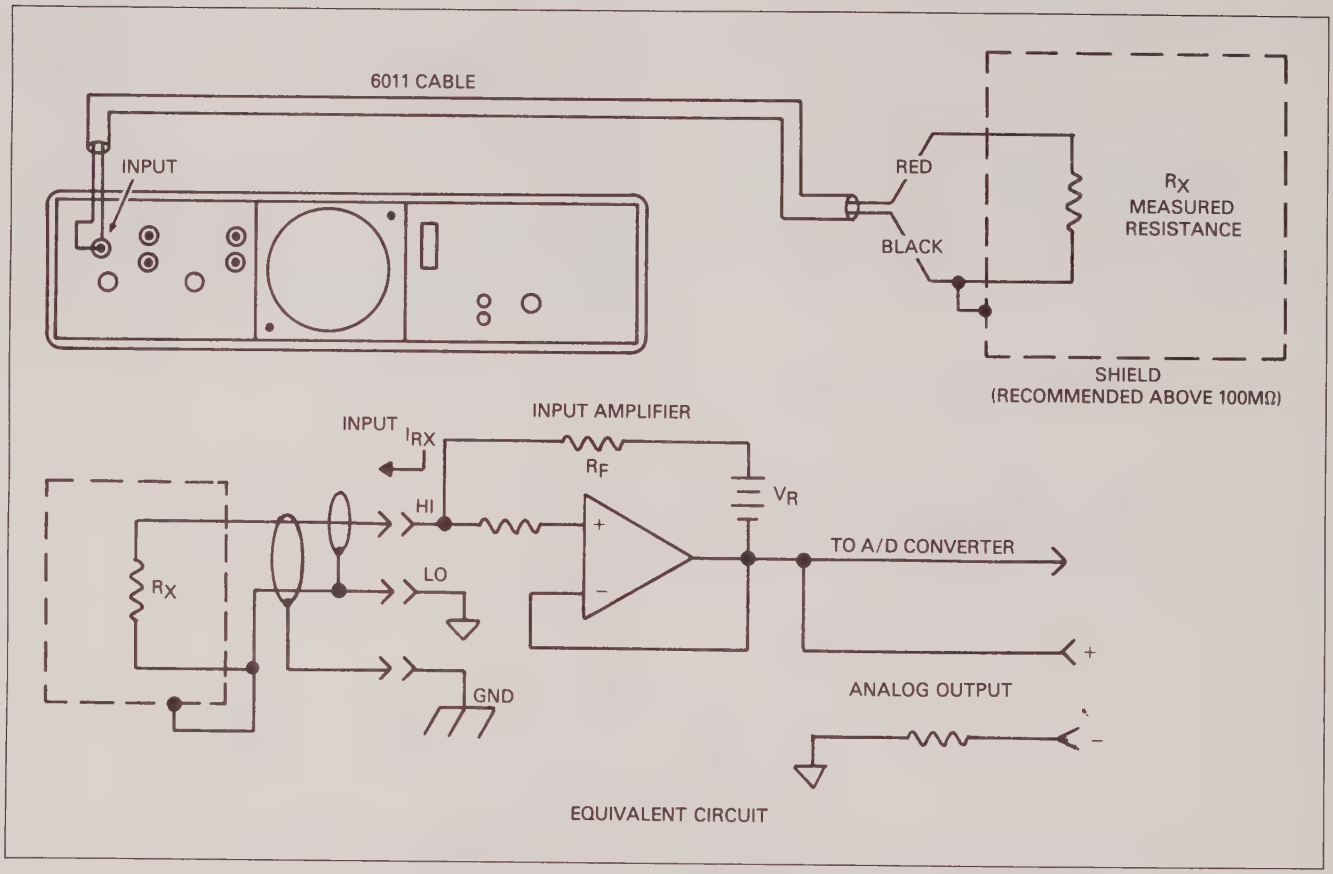


Figure 2-10. Resistance Measurement Connections

2.8.8 Using the Ohms Function as a Current Source

The Model 619 measures current by forcing a constant current through the unknown resistance and then measuring the voltage across the device. The value of the current will depend on the selected ohms range, as summarized in Table 2-3.

Table 2-3. Ohms Function Output Current Values

Ohms Range	Output Current	Maximum Output Voltage
2kΩ, 20kΩ	100μA	5V
200kΩ, 2MΩ	1μA	5V
20MΩ, 200MΩ	10nA	5V
2GΩ	10nA	300V
20GΩ-2TΩ	100pA	300V

To use the Model 619 in this manner, simply connect the Model 6011 cable to the INPUT jack of the desired channel. Connect the alligator clips across the device. Note that current flows from input high (red clip) to input low (black clip). The test voltage will be less than 5V for all ranges except for the 2GΩ through 2TΩ ranges, where a maximum of 300V will appear across the test circuit under overload conditions.

For possible applications of this feature, refer to Section 4.

2.9 DUAL CHANNEL OPERATION

If a second Model 6194 Electrometer Module is installed in the channel B location, the Model 619 may be used on a dual-channel basis. The following paragraphs describe the basic procedures for using the instrument in this manner, as well as ratio and difference functions, and considerations when using two channels with the Model 619.

2.9.1 Channel Selection

Selecting the desired button is simply a matter of pushing the appropriate front panel pushbutton, CHANNEL A or CHANNEL B. The operational channel is indicated by either the CHANNEL A or CHANNEL B annunciator. If the CHANNEL B button is pressed and no module is present in that channel, the following message will be displayed:

no ch-b

Since each electrometer module operates independently, each channel may be separately programmed for the various operating modes such as measuring function, ranging, zero check and zero correct, baseline store , baseline suppression, filtering and resolution. Thus, it is possible to set up channel A to measure volts in autoranging with 4½ digit resolution while configuring channel B to measure current with 5½ digit resolution and in manual ranging.

2.9.2 Ratio A/B and Difference A-B

In any function and range, the ratio or difference between channels A and B, from 10^{-18} to 10^{18} may be calculated and displayed.

Ratio A/B—To enter this mode, simply press the RATIO A/B button. If the channel B module is present, the instrument will enter the ratio mode, turn on the RATIO A/B indicator, and perform the following measuring sequence:

1. Take one reading at a rate of 4.8rdgs/sec on channel A.
2. Take one reading at a rate of 4.8rdgs/sec on channel B.
3. Compute the ratio A/B and display the result at 2.4rdgs/sec with 5½ digit resolution.
4. Repeat the above sequence.

Difference A-B—Press the DIFFERENCE A-B button to enter this mode. If the channel B module is present, the instrument will enter the difference mode, turn on the DIFFERENCE A-B indicator, and perform the following measurement sequence:

1. Take one reading at a rate of 4.8rdgs/sec on channel A.
2. Take one reading at a rate of 4.8rdgs/sec on channel B.
3. Compute the difference A-B and display the result at a rate of 2.4rdgs/sec with 5½ digit resolution.
4. Repeat the above sequence.

NOTES:

1. If the Model 6193 IEEE-488 option is installed, the unit must be in the talk-only mode to use the ratio or difference functions. The talk-only mode may be selected by placing the TALK/ONLY/ADDR DIP switch on the rear panel to the TALK ONLY position. The TALK and TALK ONLY front panel indicators will be on when the instrument is set to this mode. Note that the instrument must be momentarily powered down to recognize a new switch position.
2. Pressing the RATIO A/B or DIFFERENCE A-B buttons when no module is located in the channel B location will result in the "no ch-b" error message. The instrument will remain on channel A under these conditions.
3. The largest value that can be displayed in the ratio or difference mode is 1999.99×10^{18}. The smallest value that can be displayed is 0.00000×10^{-18}. Any time a division by zero is attempted, the "OFLO" message will be displayed. Since internal data is stored with higher resolution than displayed data, a display of all zeroes will not necessarily result in a ratio overflow indication.
4. The remaining front panel buttons (such as VOLTS, ZERO CHECK, and RESOLUTION) are locked out when the ratio or difference modes are enabled. To change one of these operating parameters, press the CHANNEL A or CHANNEL B, as desired, and then make the necessary changes. Return to the ratio or difference mode in the usual manner.

2.9.3 Channel Isolation Considerations

The two electrometer modules operate independently of one another. However, since they are mounted in a common chassis and share certain power supplies, some leakage paths between the two modules do exist.

Figure 2-11 shows a simplified leakage path model for the Model 619. Each electrometer module input has a high input, a low (signal common) input, and a chassis ground connection. Each module also has a power supply driven by a power transformer. Since no transformer has perfect isolation, a small leakage path between signal common and chassis ground is set up. In Figure 2-11, these leakage paths are represented as R_A and C_A for channel A, and R_B and C_B for channel B.

These leakage paths could create problems in certain situations because of the less-than-perfect isolation between channels. For example, noise present on one channel could be coupled to the other channel when switching between channels.

Another leakage path is present between the high input terminals of the two modules through a common power supply that controls the switching relays. In Figure 2-11, this leakage path is represented as C_p. While C_p has a very small value (typically about 0.5pF), its effects could be noticeable, especially for high impedance measurements. The possible ef-

fects could be twofold: a sharp transient that may be seen when switching channels, and slightly increased response time may result because the capacitance must be fully charged before the reading completely settles.

2.9.4 Autoranging In The Dual Channel Mode

Each channel in the Model 619 can be individually set up for the auto or manual ranging modes. It is important to note, however, that the instrument is monitoring the input signal for the presently selected channel. Thus, an overrange input in the unselected channel will not be dealt with until that channel is selected.

In some case, this situation could cause problems such glitches in the measurement. To avoid such problems, it may be best to place the instrument in the lowest manual range possible keeping in mind the maximum signal level to be measured.

2.9.5 Speed Considerations

Although the two electrometer modules operate independently, they do share a single A/D converter. Internally, module outputs are selected by relays located on the filter/multiplexer board. Since channel switching requires a finite time interval, rapidly switching between channels may decrease the reading rate. The amount of decrease will depend on the selected resolution, as well as how often channel switching takes place.

2.10 USING THE ANALOG OUTPUT

The analog output of the Model 619 follows the signal amplitude applied to the INPUT terminal. Some possible uses for the analog output include: buffering of the input signal, applying signals to other instruments such as chart recorders, and guarding the circuit in the volts and ohms functions.

2.10.1 Analog Output Connections

Connections for using the analog output are shown in Figure 2-12, along with basic internal configuration for the three measuring functions. In both volts and ohms the output is noninverting, while it does invert the input signal in the amps function.

WARNING
High voltage may be present between the ANALOG OUTPUT + and − terminals (see Table 2-4).

Note that the output resistance is 1kΩ. This resistance appears between the input common and the ANALOG OUTPUT terminal to keep the resistor out of the circuit when using external feedback. Full scale output values are listed in Table 2-4. Keep in mind that the values listed are absolute in that they do not include polarity. Note that the analog output feature is not available with the 2A range.

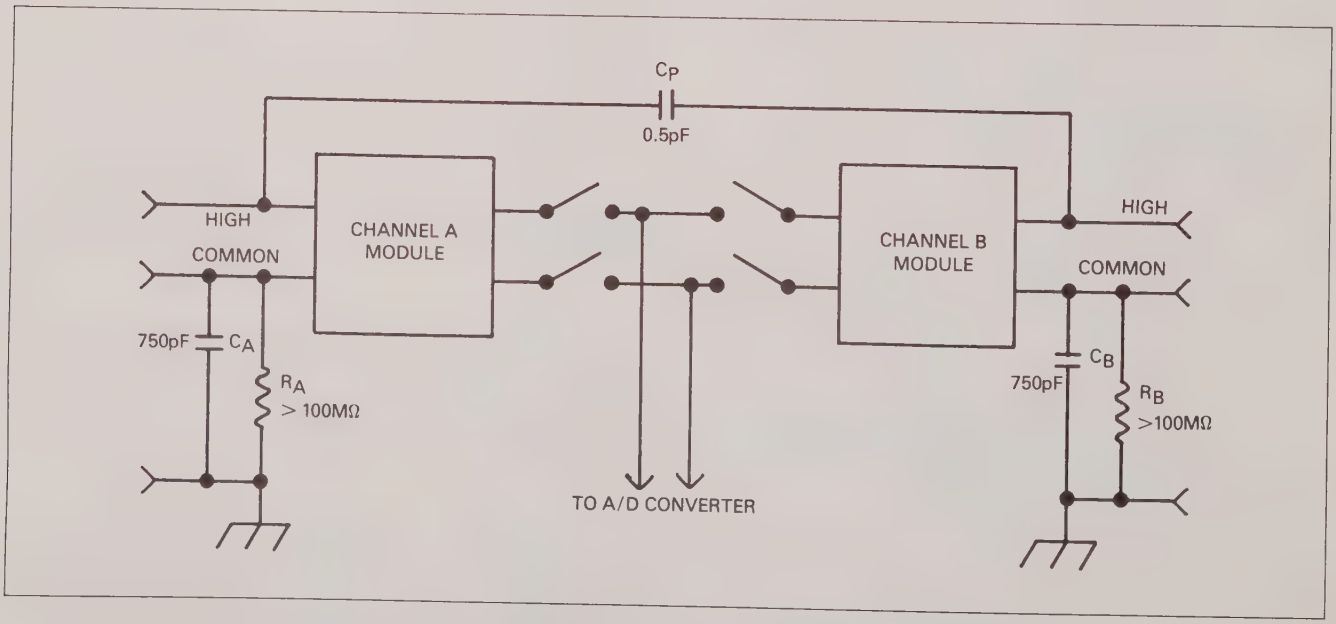


Figure 2-11. Leakage Model for Dual Channel Operation

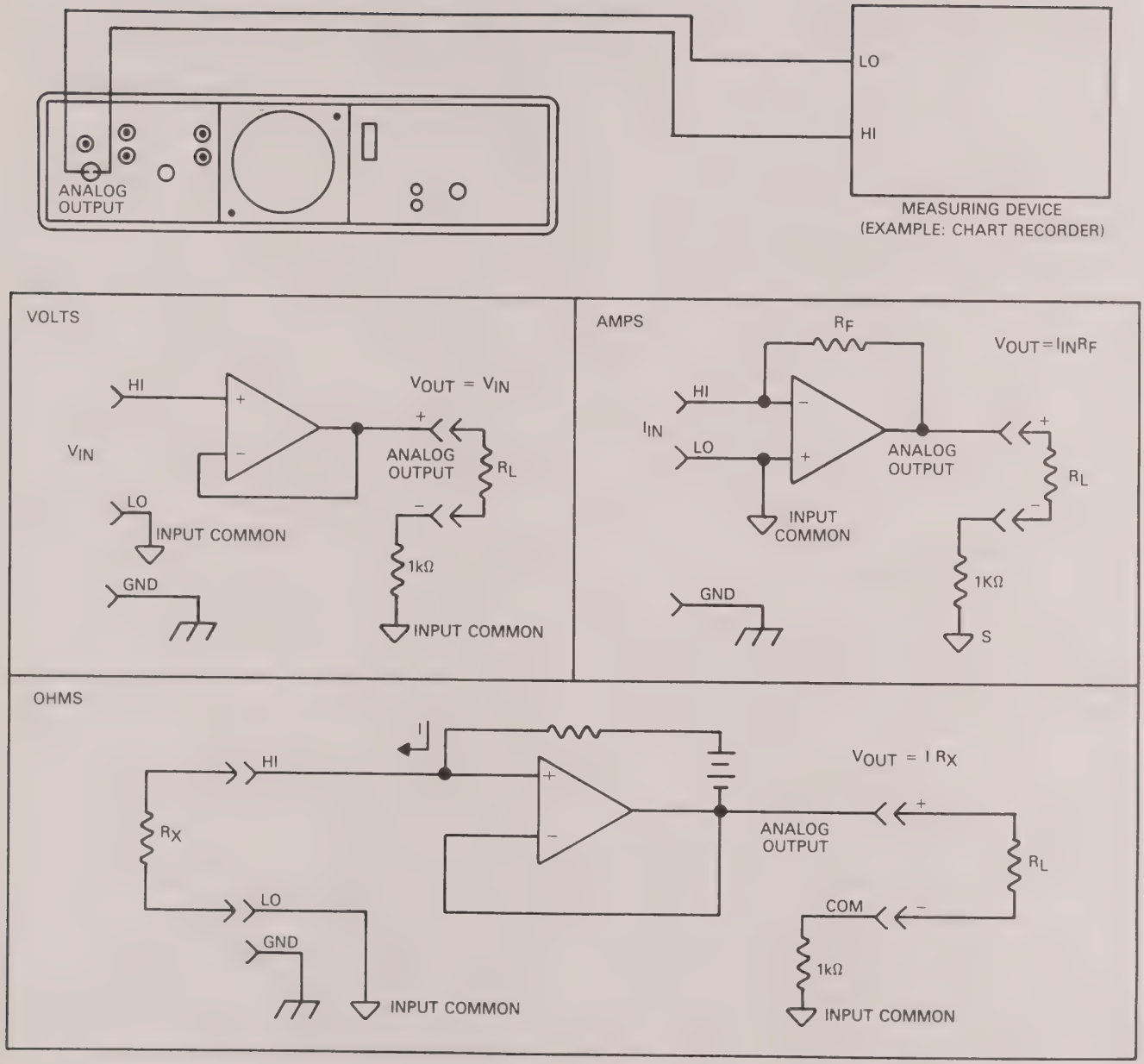


Figure 2-12. Typical Analog Output Connections

Table 2-4. Full Scale Analog Output Values

Function	Range	Full Scale Output
Volts	200mV	200mV
	2 V	2 V
	20 V	20 V
	200 V	200 V
Amps	2nA, 200nA, 20μA, 2mA	200mV
	20nA, 2μA, 200μA, 20mA	2 V
Ohms*	2kΩ, 200kΩ, 20MΩ	200mV
	20kΩ, 2MΩ, 200MΩ, 20GΩ	2 V
	2GΩ, 200GΩ	20 V
	2TΩ	200 V

*WARNING: Maximum open-circuit voltage of 300V present on 2GΩ-2TΩ ranges.

2.10.2 Guarded Operation

Guarding consists of using a conductor supplied by a low impedance source to totally surround the leads carrying a high-impedance signal. The output of this low-impedance source is kept at the same potential as the signal itself, resulting in drastically reduced leakage currents.

To approach the concept of guarding, let us first review the unguarded circuit shown in Figure 2-13. The measured signal is represented by the voltage source E_S and the source resistance R_S. Cable leakage impedance is represented by Z_L. The source resistance and leakage impedance for a voltage divider that attenuates the source voltage as follows:

$$E_O = \frac{Z_L E_S}{Z_L + R_S}$$

Thus, to keep the error due to leakage resistance under 0.1%, the leakage resistance must be at least 1000 times the source resistive value.

Guarding the circuit minimizes these effects by driving the shield at signal potential, as shown in Figure 2-14. Here, a unity gain amplifier with a high input impedance and low output impedance is used. The input of the amplifier is connected to the signal, while the output is used to drive the shield. Since the amplifier has unity gain, the potential across Z_L is essentially zero, so no leakage current flows. Leakage between the cable shield and ground may be considerable, but it is of no consequence since that current is supplied by the low impedance source, rather than by the signal itself.

In order to make guarded measurements with the Model 619, it will be necessary to use the Model 6191 Guarded Adapter. A schematic of this adapter is shown in Figure 2-15. The Model 6191 mounts right on the electrometer INPUT jack and also is equipped with the mating plug for the ANALOG OUTPUT connector. A built-in switch allows easy selection of the guarded or unguarded modes. When using the Model 6191, effective cable capacitance is typically reduced to approximately 2pF.

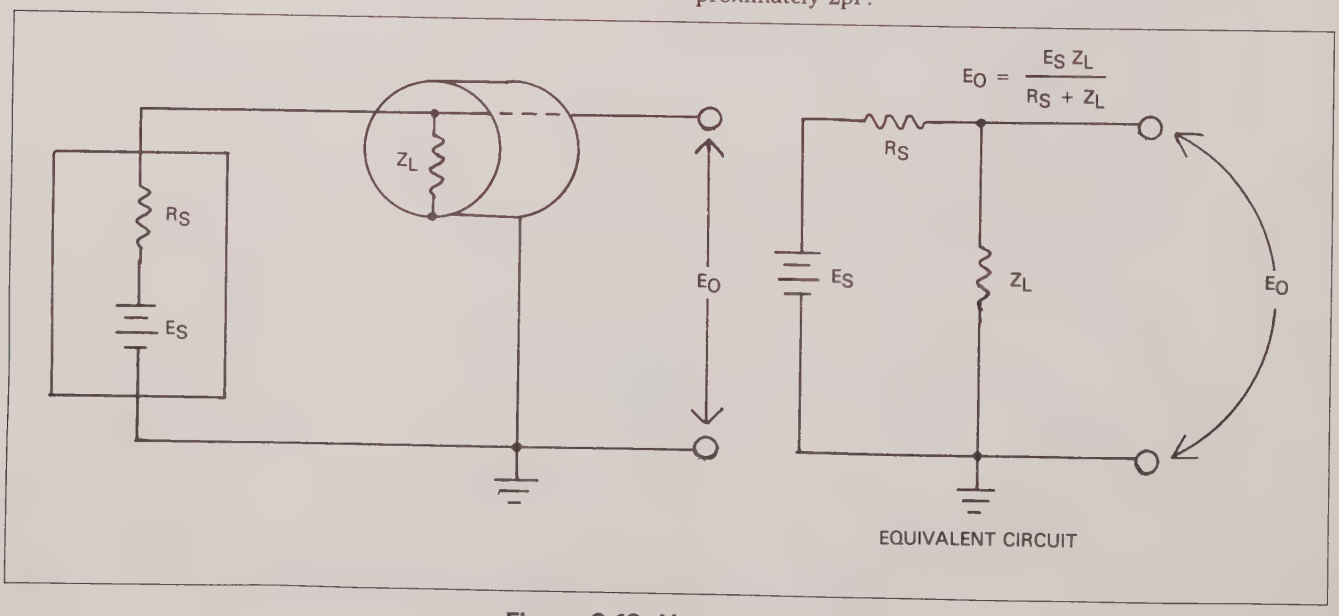


Figure 2-13. Unguarded Circuit

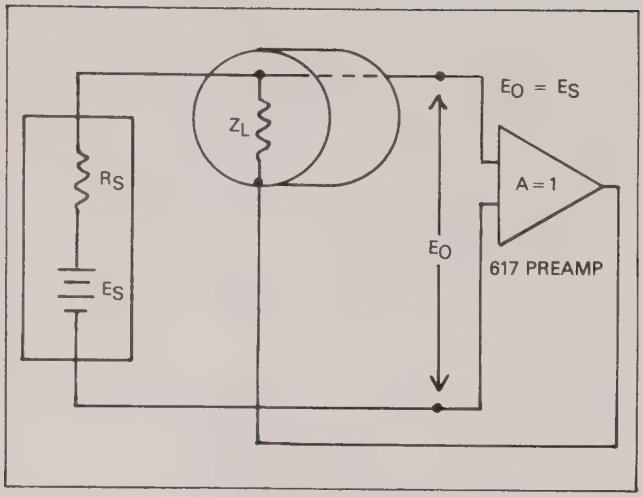


Figure 2-14. Guarded Circuit

Typical connections for using the Model 619 to make guarded measurements are shown in Figure 2-16. Note that the use of guarding in amps is not recommended.

WARNING

Hazardous voltage (up to 300V) may be present on the guard shield, depending on the input signal. A safety shield, connected to chassis ground, is recommended when making voltage measurements over 30V, or when making guarded resistance measurements.

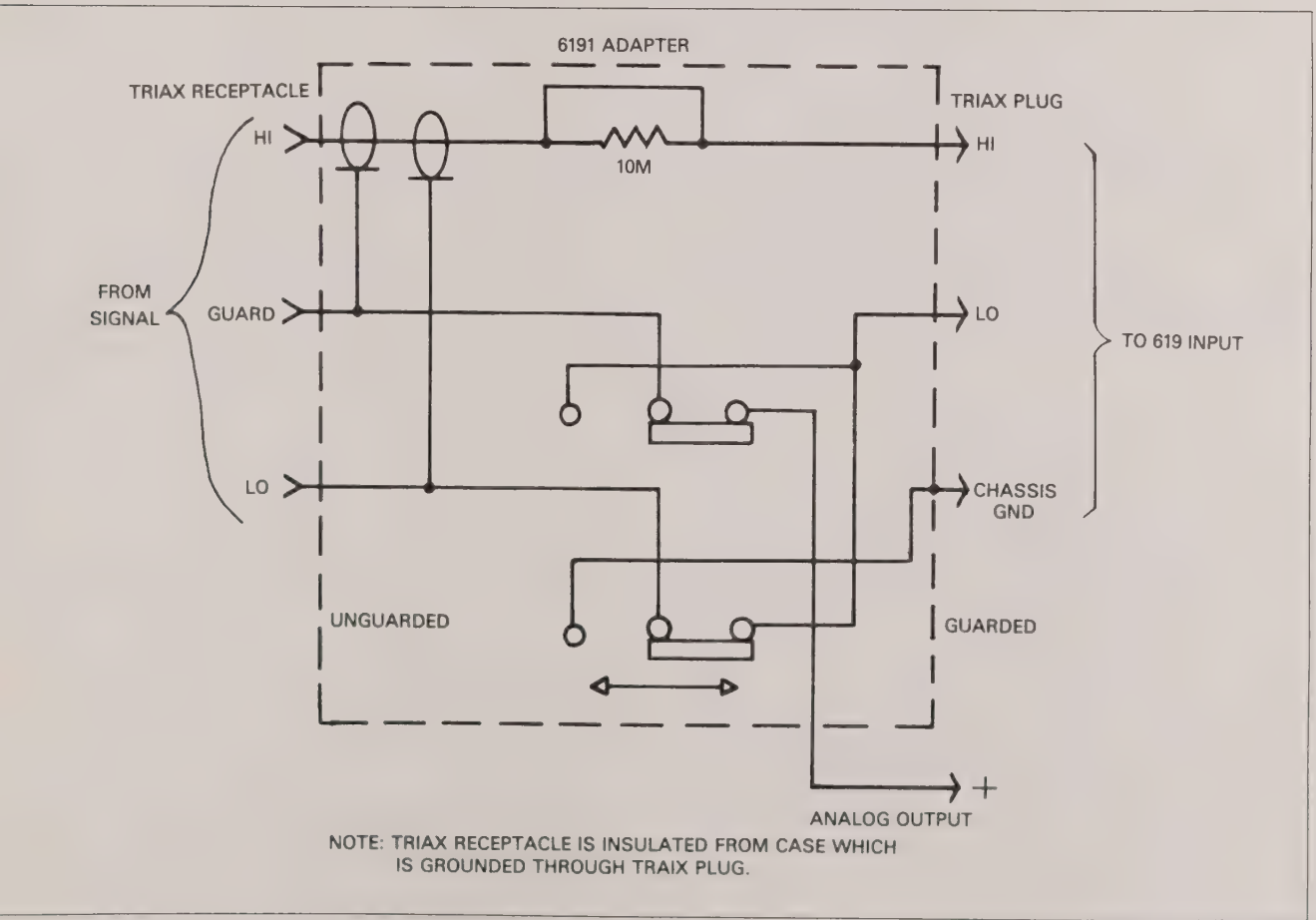


Figure 2-15. Model 6191 Guarded Adapter

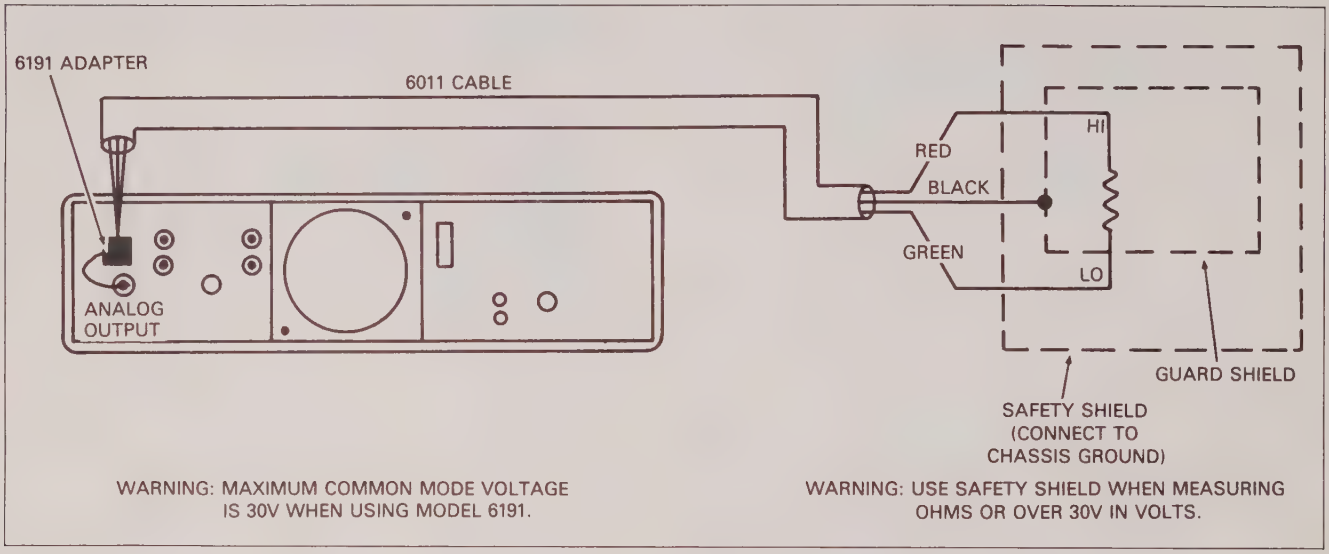


Figure 2-16. Typical Guarded Connections

2.11 USING EXTERNAL FEEDBACK

The external feedback feature provides a method to extend the capabilities of the Model 619 to such uses as logarithmic currents, non-decade current gains, as well as charge measurement. The following paragraphs discuss the basic electrometer input circuit and methods to implement these functions.

2.11.1 Electrometer Input Circuitry

The input circuitry used in the Model 6194 Electrometer Module in the amps function is configured in the feedback amps mode as illustrated in Figure 2-17. An input current applied at the negative input of the op amp is nulled with a current through the parallel combination of R_{FB} and C_{FB} from the output of the op amp. This is accomplished by the high open-loop gain (typically greater than 40,000) of the op amp which holds its negative input at virtual ground (its positive input which is connected to input common). R_{FB} in parallel with C_{FB} converts the input current to a voltage which is further processed by the A/D converter in the Model 619. Included in this processing is a re-inversion of the signal polarity to match that of the actual input.

The availability of the analog output permits the user to substitute an external network for the combination of R_{FB} and C_{FB}. In effectively applying the capability, a number of factors must be taken into account.

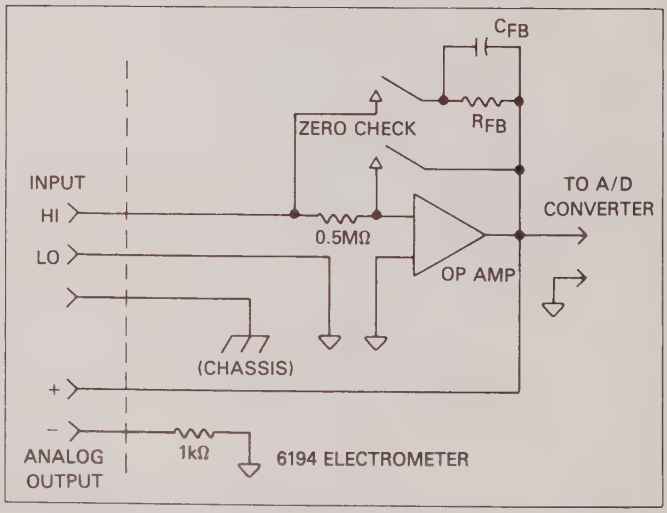


Figure 2-17. Model 6194 Electrometer Input Circuitry

1. The total absolute value current supplied by the analog output for both feedback to the input and monitoring of the analog output must be less than 22mA.
2. The Model 619 processes the Model 6194 Electrometer output as a ±2.0000VDC (±2.00000VDC in the 5½ digit mode) signal correctly inverting the polarity for an accurate representation of the input signal polarity. This out-

put voltage is the level impressed across the external feedback network.

3. Accuracy of the response is the same as that for the 2V range, excluding the contribution of all user-supplied external feedback circuitry. Noise and NMRR will also be a function of this external circuitry.
4. Input impedance is given by the relationship $Z_{IN}=0.5M\Omega\|(Z_{FB}/A_V)$, where Z_{FB} is the external feedback network and A_V is the open-loop gain of the op amp (typically greater than 40,000). Note that in zero check, A_V is reduced to unity (1) and the $\|$ represents the parallel combination of the two quantities separated by this symbol: $(A\|B)=AB/(A+B)$.
5. Selection of the external feedback network must incorporate the proper frequency compensation required by the Model 6194 Electrometer Module.
6. All external feedback circuitry should be housed in a suitable shielded enclosure. Insulators supporting the input mode (input HI) should be constructed of Teflon or other high quality insualtor.

2.11.2 Shielded Fixture Construction

Since shielding is so critical for proper operation of external feedback, it is recommended that a shielded fixture similar to the one in Figure 2-18 be used to house the feedback element. The fixture is constructed of a Pomona #2390 shielded fixture modified with a standard BNC connectors replaced with triaxial female connectors. For convenience, a banana jack can be mounted on the box to make the necessary connection. Alternately, a wire could be run through a rubber grommet mounted in a hole in the slide of the box. Note that input low is connected to chassis ground within the shielded box. This connection can be made by using a small solder lug secured with a screw.

2.11.3 External Feedback Procedure

Use the following basic procedure to operate the Model 619 in the external feedback mode.

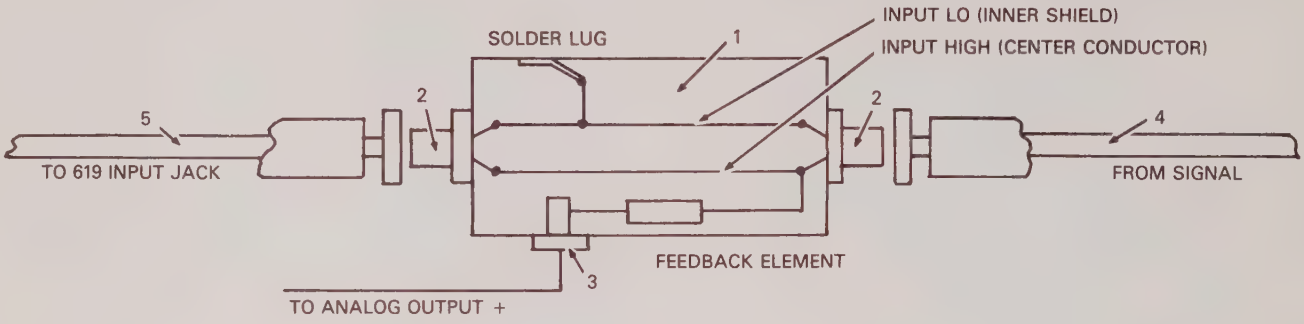
1. Place the instrument on the 2nA range and enable zero check.
2. Press the ZERO CORRECT button to zero the instrument.
3. Connect the feedback element between the ANALOG OUTPUT + terminal and the input high terminal (see Figure 2-18).
4. Place the instrument in the external feedback mode by repeatedly pressing UPRANGE until the EXT FEEDBACK indicator turns on. Note that no autoranging is available with the external feedback. Pressing AUTO/MANUAL while in this mode will result in the "no Au" message.
5. Disable zero check. The display will show the voltage, as measured at the ANALOG OUTPUT + terminal.
6. To cancel the external feedback mode, press the DOWNRANGE button, or select the volts or ohms measuring functions.

2.11.4 Charge Measurement

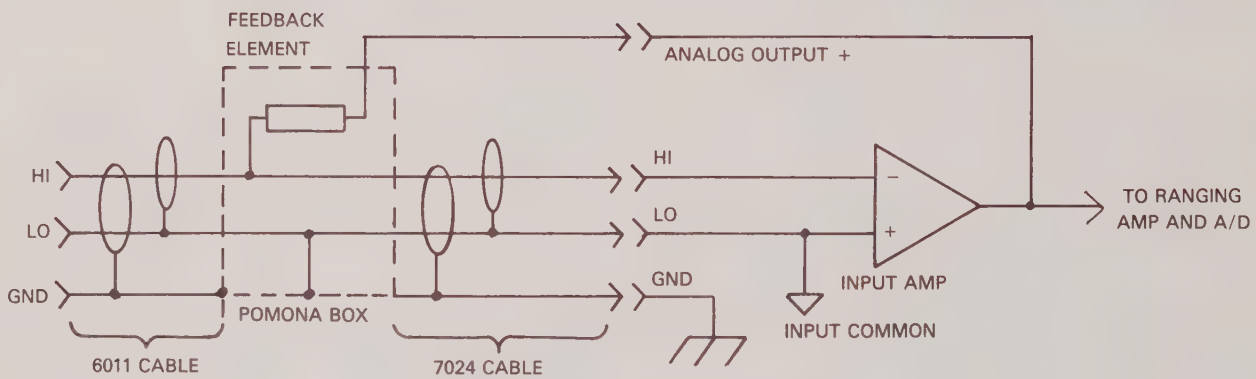
The measurement of charge can be made directly by using an external feedback capacitor, C_{FB}, as illustrated in Figure 2-19. In the relationship $Q=CV$, Q=charge (coulombs) applied to input, C=capacitance (farads) of C_F, and V=voltage (volts) at output as indicated on the display. The Model 619 display will read charge directly in the units determined by C. For example, using $1\mu F$ capacitor will provide a display in μC.

In practice, C_{FB} should be greater than 100pF for feedback stability and of a suitable dielectric material to ensure low leakage and low dielectric absorption. Polystyrene and polypropylene dielectric capacitors offer good performance in this regard.

As shown in Figure 2-19 and external zero check contact may be desirable in certain applications where $0.5M\Omega$ zero check input impedance cannot be tolerated. R_{LIMIT} protects this contact from the discharge surge of C_{FB}. Care should be exercised in the selection of this contact (switch or relay) that the high impedance, low current requirements of the circuitry are not compromised.



A. CONSTRUCTION



B. EQUIVALENT CIRCUIT

PARTS LIST

ITEM	DESCRIPTION	MFR. PART NUMBER
1	SHIELDED FIXTURE	POMONA #2390
2	FEMALE TRIAXIAL	KEITHLEY CS-181
3	BANANA JACK	KEITHLEY BJ-9-2
4	TRIAXIAL CABLE	KEITHLEY 6011
5	TRIAXIAL CABLE	KEITHLEY 7024

Figure 2-18. Shielded Fixture Constructions

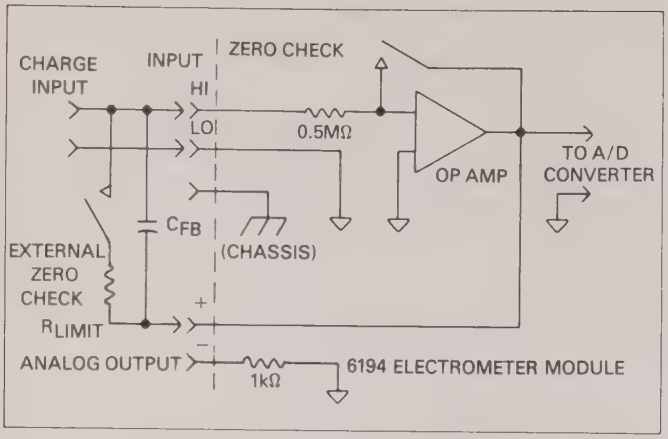


Figure 2-19. Charge Measurement

2.11.5 Logarithmic Currents

The use of a diode junction in the external feedback path permits a logarithmic current-to-voltage conversion. This relationship for a junction diode can be given by the equation:

$$V = mkT/q\ln(I/I_O) + IR_B$$

Where q=unit charge (1.6022×10^{-19}C), k=Boltmann's constant (1.3806×10^{-23}J/°K), and T=Temperature (°K).

The limitations in this equation center on the factors I_O, m, and R_B. I_O is the extrapolated current for V=0. An emperical proportional constant, m, accounts for the different character of current conduction (i.e., recombination and diffusion) mechanisms within the junction, typically varying in value between 1 and 2. Finally, R_B constitutes the ohmic bulk resistance of the diode junction material. I_O and R_B limit the usefulness of the junction diode as a log converter at low and high currents, respectively. The factor m introduces nonlinearities between these two extremes. With all these factors taken into account, most diodes have a limited range of useful logarithmic behavior.

A solution to these constraints is the use of a transistor configured as a "transdiode" in the feedback path as shown in Figure 2-20. Analyzing the transistor in this configuration leads to the relationship:

$$V = kT/q[\ln I/I_O - \ln)h_{FE}/1 + h_{FE}))]$$

where h_{FE} is the current gain of the transistor.

From this equation, proper selection of transistor Q1 (Figure 2-20) would require a device with a high current gain (h_{FE}) which is maintained over a wide range of emitter currents. Suitable devices include analog devices AD812 and precision monolithics MAT-01.

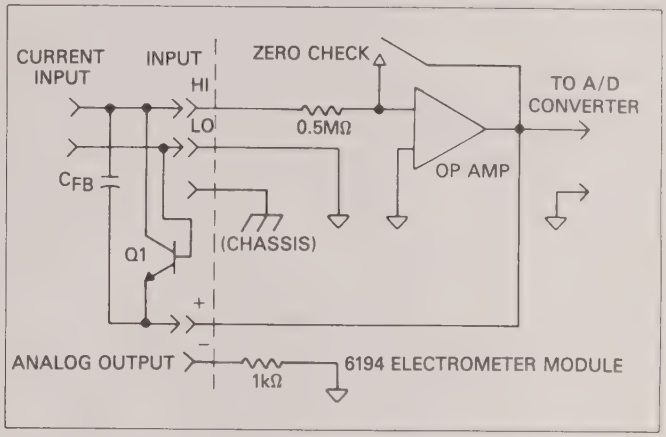


Figure 2-20. Logarithmic Current Measurement

Frequency compensation/stabilization is accomplished by C_{FB}. Selection of a proper value depends on the particular transistor being used and the maximum current level anticipated. Compensation at the maximum current is required since the dynamic impedance of the transistor will be a minimum at this point. It should be noted that the response speed at lower currents will be compromised due to the increasing dynamic impedance.

$$Z(\text{impedance}) = dV/dI = kT/qI = 0.026/I@25°C$$

Using the MAT-01 or AD818, a minimum RC time constant of 50sec at maximum input current should be used. At I_{IN} (max) of 100μA, this would correspond to 0.2μF. Note that at 100nA, this would increase the RC response time constant to 50msec (5sec at 1nA). A minimum capacitance of 1000pF is recommended.

Although the input to this configuration is a current source, a voltage source can be used with a suitable ballast resistor. In this configuration, the input burden of 1mV must be considered as an error source against the input voltage.

Further processing of the response can be accomplished with baseline suppression and ratio. Baseline suppression provides an offset and ratio provides a scaling factor (with optional channel B, Model 6194 Electrometer Module installed). Alternately, a controller (computer) can process the data via the IEEE-488 bus output (with optional Model 6193 IEEE interface installed).

2.11.6 Non-Decade Current Gains

The Model 6194 Electrometer uses internal decade resistance feedback networks for the 2nA through 20mA current ranges. In some applications a non-decade current-to-voltage conversion (gain) may be desirable. As illustrated in Figure 2-21 a calibration resistance, R_{FB}, serves this purpose.

Limitations on the value of R_{FB} require it to be in the range of $10^2\Omega$ to $10^{10}\Omega$. Frequency compensation/stabilization is accomplished by C_{FB}. Selection of C_{FB} based on an RC response time should be per Table 2-5 with a minimum value of 100pF.

Table 2-5. C_{FB} Selection

R_{FB}	RC Response Time
10^2 to 10^3	50μsec
10^5 to 10^6	500μsec
10^6 to 10^7	5msec
10^7 to 10^{10}	C = 100pF

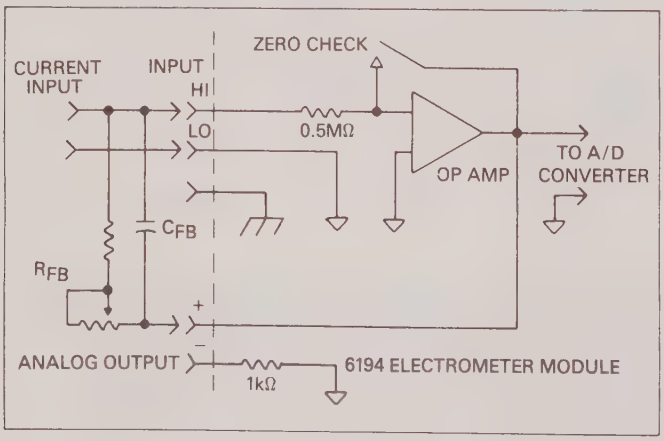


Figure 2-21. Non-Decade Current Gain Measurement

2.12 ZERO CHECK AND ZERO CORRECT

The ZERO CHECK and ZERO CORRECT buttons work together to cancel any internal offsets that might upset accuracy. Use the following procedure to zero correct the instrument. Note that zero correction should always be performed on the lowest range of the selected function. Six separate registers, one for each channel/function combination are available for zero correct.

NOTE

Do not attempt to zero correct the instrument while in the autorange mode.

1. Select the lowest range of the function being used.
2. Enable zero check by pressing the ZERO CHECK button, if not already enabled (the instrument is placed in zero check upon power up).

NOTE

The equivalent impedance changes with zero check enabled, as indicated in Figure 2-22.

3. Press ZERO CORRECT to perform the correction process.
4. To take readings, press ZERO CHECK to disable zero check.
5. Readings can now be taken in a normal manner. Note that the instrument will remain zero corrected when the instrument is upranged.

If the instrument is in the zero check mode, pressing ZERO CORRECT will result in the following sequence:

1. The filter will be disabled.
2. The A/D converter will be placed in the X10 gain and 16.66msec integration modes.
3. Two conversions will be averaged.
4. Two readings will be taken, one with the electrometer attenuator set for −1, and a second with the attenuator set for −10.
5. A/D converter and electrometer offsets will be calculated.
6. The above steps will be repeated for the 100msec integration period.
7. The instrument will return to the previous operating mode with zero check enabled. Subsequent readings will be compensated for internal offsets by using parameters derived during the above procedure.

Notes:

1. For maximum accuracy, zero correction should be performed whenever the function is changed.
2. Zero check should be enabled when connecting or disconnecting input cables, unless the reduced input impedance might have detrimental effects on the signal being measured.
3. Pressing ZERO CORRECT with zero check disabled will result in the "Corr II" error message.
4. Zero check and zero correct cannot be used with the 2A current range. Pressing ZERO CHECK while in this range will result in the "no 2A C" error message.
5. Zero check and zero correct are not available in the ratio and difference modes.

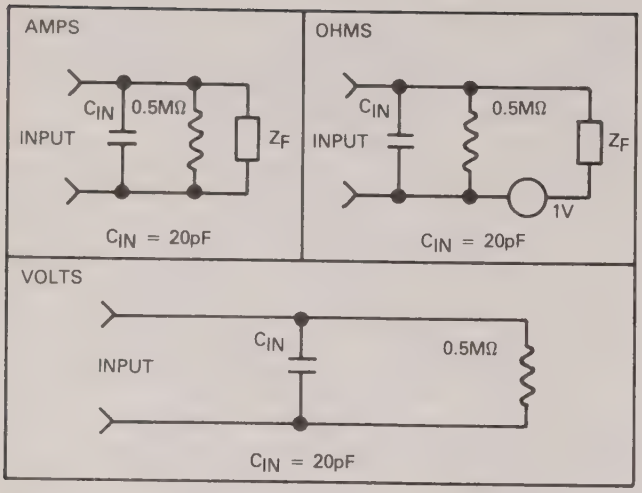


Figure 2-22. Equivalent Input Impedance with Zero Check Enabled

2.13 BASELINE STORE AND BASELINE SUPPRESSION

The BASELINE STORE and BASELINE SUPPRESSION buttons work in conjunction with one another to allow a stored baseline value to be subtracted from subsequent readings. For example, if 1kΩ is stored as a baseline value with the instrument on the 20kΩ range, measuring a 10kΩ resistor with baseline suppression enabled will result in a displayed reading of 9kΩ. Six separate baseline values may be stored: channel A volts, channel A amps, channel A ohms, channel B volts, channel B amps and channel B ohms (of course, the channel B storage registers are available only if the instrument is equipped for dual channel operation).

The suppressed reading can be as small as the resolution of the instrument, or as large as full range.

To store baseline values, perform the following sequence.

1. Select a range and function that is consistent with the anticipated measurement.
2. Connect the signal to be suppressed to the instrument input. Disable zero check.
3. Press the BASELINE STORE button to store the value. If the baseline suppression mode is enabled, it will be cancelled at this point.
4. Repeat steps 1 through 3 for the remaining measuring functions and the other channel, if desired.

Once baseline values are stored, they can be used with subsequent measurements simply by applying the measured signal and pressing the BASELINE SUPPRESSION button; the SUPPRESSION LED will then turn on. Displayed readings will then be the difference between the actual signal level and the stored value. Separate suppression modes may be applied to channels A and B. Some examples are:

Applied Signal	Suppressed Value	Display Reading
+18.600V	+10.500V	+8.100V
+1.8000nA	+2.556nA	−0.7560nA
12.600MΩ	4.500MΩ	8.100mV

To cancel this mode, press BASELINE SUPPRESSION a second time.

WARNING

The voltage on the input terminals may be larger than the displayed value when baseline suppression is enabled. For example, if a 150VDC baseline is stored, an applied voltage of +175V will result in a displayed reading of only +25V. The SUPPRESSION LED will flash when the instrument is on the 200V range to indicate a possible safety hazard.

Notes:

1. Using baseline suppression reduces the dynamic range of the measurement. For example, if the stored baseline is 1.2kΩ on the 2kΩ range, an applied signal of 800Ω or more will overrange the instrument even though 800Ω is well within the capabilities of the 2kΩ range when baseline suppression is disabled.
2. Setting the range lower than the stored baseline value will overrange the display.
3. Baseline store and baseline suppression are not available in the ratio and difference modes. These buttons will be locked out if ratio or difference are enabled.

2.14 FILTER

When the filter is enabled, either by pressing the front panel FILTER button, or by sending the filter command over the IEEE-488 bus (see Section 3), an additional 25dB of line frequency rejection filtering is applied to the input signal. While the filter is enabled, the front panel FILTER annunciator will be on. The filter mode may be cancelled by pressing the FILTER button a second time. Separate filter mode may be applied to channels A and B.

NOTE

The filter mode is not available when the instrument is in the ratio or difference modes.

2.15 RESOLUTION

The Model 619 display may be operated in either the 4½ or 5½ digit resolution modes. The display may be toggled between these two modes by pressing the RESOLUTION button. Each time RESOLUTION is pressed, the instrument will switch to the alternate mode.

In the 4½ digit mode, the unit will update the display at a rate of 6.2 readings per second. Switching to 5½ digit resolution will decrease the rate to 2.4 readings per second. Note that the instrument will be in the 4½ digit mode upon power up.

Notes:

1. The RESOLUTION button will be locked out in the ratio or difference modes. Resolution of 5½ digits is automatically selected for these two modes.
2. The RESOLUTION button affects only the mantissa of the display; the exponent is not affected.
3. The RESOLUTION button is also used to place the instrument in the T1 trigger mode, as described in paragraph 2.16.
4. Each channel of the Model 619 (with those instruments so equipped) may be operated separately with 4½ or 5½ digit resolution.

2.16 EXTERNAL TRIGGERING

The Model 619 has two external BNC connectors on the rear panel associated with the instrument triggering. The EXTERNAL TRIGGER input allows the instrument to be triggered by other devices, while ELECTROMETER COMPLETE output allows the instrument to trigger other devices.

2.16.1 External Trigger

The Model 619 may be triggered on a continuous or one-shot basis. For each of these modes, the trigger stimulus will depend on the selected trigger mode, which is further described in Section 3. In a continuous trigger mode, the instrument takes a continuous series of readings. In a one-shot mode, only a single reading is taken each time the instrument is triggered.

The EXTERNAL TRIGGER input requires a falling edge pulse at TTL logic levels, as shown in Figure 2-23. Connections to the rear panel EXTERNAL TRIGGER input jack should be made with a standard BNC connector.

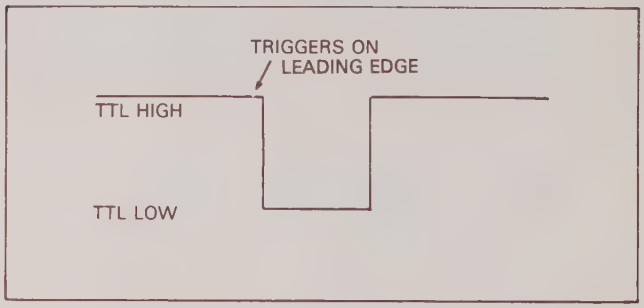


Figure 2-23. External Trigger Pulse Specifications

Generally, the instrument will be used in the one-shot trigger mode when being externally triggered. To use the instrument in the T1 trigger mode with external triggering either program that mode over the bus (see Section 3), or perform the following sequence:

1. Set the internal trigger mode switch to the correct trigger position, as described in Section 7.
2. Turn on the power to the instrument.
3. Select the desired range, function and other operating parameters such as channel, as required.
4. Press the RESOLUTION button to enter the one-shot trigger mode. The instrument will also be placed in the 5½ digit resolution mode at this point.
5. To trigger the instrument, either apply an appropriate trigger pulse at the EXTERNAL TRIGGER input, or push the RATIO A/B or DIFFERENCE A-B button. The reading will be triggered, and the display will be updated once each time a trigger is applied.
6. To remove the instrument from the one-shot mode, power must be turned off. Note, however, that each channel may be programmed separately for one-shot triggering by selecting the channel and pressing RESOLUTION at the appropriate time.
7. To permanently disable one-shot triggering, place the internal trigger switch in the disabled position, as described in Section 7.

2.16.2 Electrometer Complete

The Model 619 has an available output pulse that can be used to trigger other instrumentation. A single TTL-compatible

positive-going pulse with a minimum duration of 400μsec (see Figure 2-24) will appear at the ELECTROMETER COMPLETE output jack each time the instrument completes a reading. To use the electrometer complete output, proceed as follows:

1. Connect the Model 619 to the instrument to be triggered with a suitable shielded cable. Use a standard BNC connector to make the connection to the Model 619.
2. Select the desired function, range, trigger mode and other operating parameters, as desired.
3. In a continuous trigger mode, the instrument will output pulses at the conversion rate; each pulse will occur after the Model 619 has completed a conversion.
4. In a one-shot trigger mode, the Model 619 will output a pulse once each time it is triggered after it completes the reading conversion.

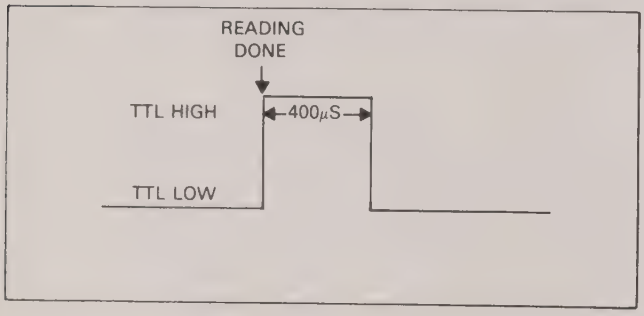


Figure 2-24. Meter Complete Pulse Specifications

2.16.3 Trigger Example

As an example of using both the external trigger input and the electrometer complete output, assume that the Model 619 is to be used on conjunction with a Keithley Model 705 Scanner to allow the Model 619 to measure a number of different signals, which are to be switched by the scanner. The Model 705 can switch up to 20 2-pole channels (20 single-pole channels with special cards such as the low-current card). In this manner, a single Model 619 could monitor up to 20 measurement points.

By triggering the Model 619 with the Model 705, a complete automatic measurement sequence could be performed. Data obtained from each measurement point could be sent over the IEEE-488 bus to a printer, which would print out the data for each point as it is measured.

Once the Model 705 is programmed for its scan sequence, the measurement procedure is set to begin. When the Model 705 closes the selected channel, it triggers the Model 619 to take a reading. The Model 705 then scans to the next channel. The process repeats until all channels have been scanned.

To use the Model 619 with the Model 705, proceed as follows:

1. Connect the Model 619 to the Model 705 as shown in Figure 2-25. Use shielded cables with BNC connectors. The Model 619 EXTERNAL TRIGGER input should be connected to the Model 705 CHANNEL READY OUTPUT. Additonal connections, which are not shown on the diagram, will also be necessary to apply signal inputs to the scanner cards, as well as for the signal lines between the scanner and the Model 619.
2. Place the Model 619 in the one-shot trigger mode as described previously.
3. Program the Model 705 scan parameters such as first and last channel as required. Place the instrument in the single scan mode.
4. Install the desired scanner cards and make the required input and output signal connections. See the Model 705 Instruction Manual for details.
5. Begin the measurement sequence by pressing the Model 705 START/STOP button. The Model 705 will close the first channel and trigger the Model 619 to take a reading. The process repeats until all programmed channels have been scanned.

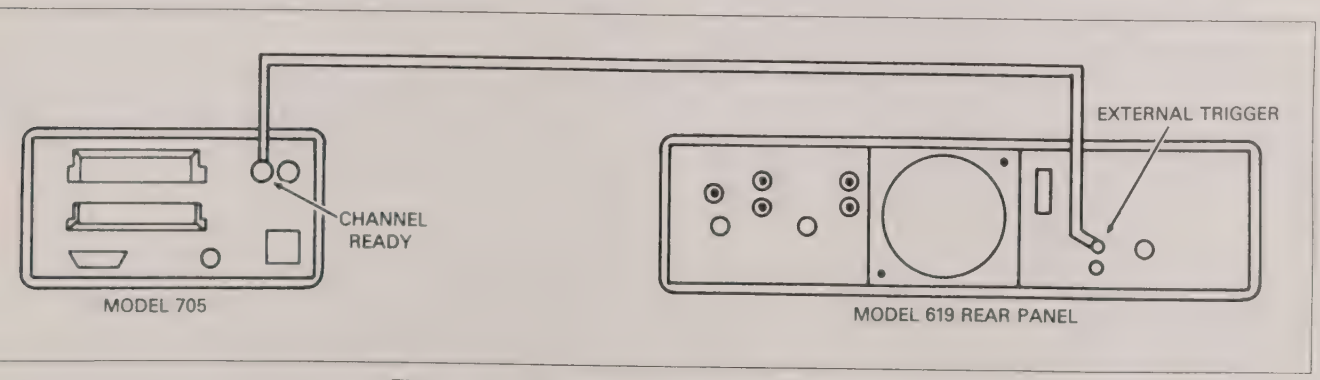


Figure 2-25. External Triggering Example

2.17 MEASUREMENT CONSIDERATIONS

The Model 619 is a sensitive instrument that can measure very low signal levels. At these low signal levels, a number of factors can affect a measurement. Some considerations when making measurements with the Model 619 are discussed in the following paragraphs.

2.17.1 Ground Loops

Ground loops that occur in multiple-instrument test setups can create error signals that cause erratic or erroneous measurements. The configuration shown in Figure 2-26 introduces errors in two ways. Large ground currents flowing in one of the wires will encounter small resistances either in the wires, or at the connecting points. This small resistance results in voltage drops that can affect the measurement. Even if the ground loop currents are small, magnetic flux cutting across the large loops formed by the ground leads can induce sufficient voltages to disturb sensitive measurements.

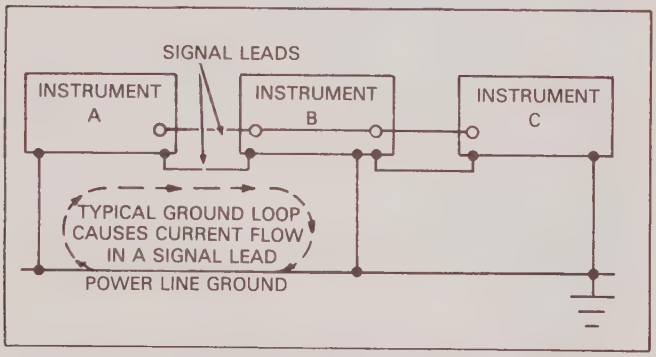


Figure 2-26. Multiple Ground Points Create a Ground Loop

To prevent ground loops, instrument should be connected to ground at only a single point, as shown in Figure 2-27. Note that only a single instrument is connected directly to power line ground. Experimentation is the best way to determine an acceptable arrangement. For this purpose, measuring instruments should be placed on their lowest ranges. The configuration that results in the lowest noise signal is the one that should be used.

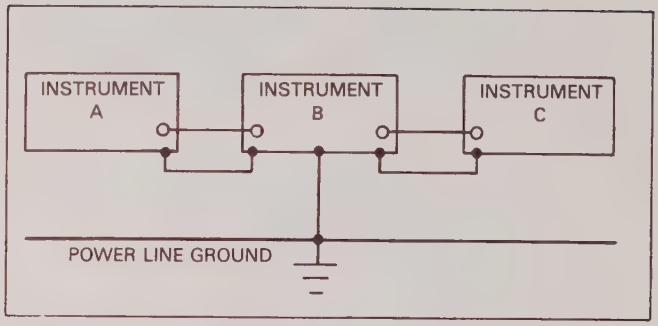


Figure 2-27. Eliminating Ground Loops

2.17.2 Electrostatic Interference

Electrostatic interference occurs when an electrically charged object is brought near an uncharged object, thus inducing a charge on the previously uncharged object. Usually, effects of such electrostatic action are not noticeable because low impedance levels allow the induced charge to dissipate quickly. However, the high impedance levels of many Model 619 electrometer measurements do not allow these charges to decay rapidly, and erroneous or unstable readings may result. These erroneous or unstable readings may be caused in the following ways:

1. DC electrostatic field can cause undetected errors or noise in the reading.
2. AC electrostatic fields can cause errors by driving the amplifier into saturation or through rectification that produces DC errors.

Electrostatic interference is first recognizable when hand or body movements near the experiment cause fluctuations in the reading. Pick up from AC fields can also be detected by observing the electrometer output on an oscilloscope. Line frequency signals on the output are an indication that electrostatic interference is present.

Means of minimizing electrostatic interference include:

1. Shielding. Possibilities include: a shielded room, a shielded booth, shielding the sensitive circuit, and using shielded cable. The shield should always be connected to a solid connector that is connected to signal low. If circuit low is floated above ground, observe safety precautions when

touching the shield. Meshed screen or loosely braided cable could be inadequate for high impedances, or in strong fields. The Keithley Model 6104 Test Shield can provide shielding under many circumstances. Note, however, that shielding can increase capacitance in the measurement circuit, possibly slowing down response time.

2. Reduction of electrostatic fields. Moving power lines or other sources away from the experiment reduces the amount of electrostatic interference seen in the measurement.

2.17.3 Thermal EMFs

Thermal EMFs are small electric potentials generated by differences in temperature at the junction of two dissimilar metals. Low thermal connections should be used whenever thermal EMFs are known to be a problem. Crimped or cadmium soldered copper to copper connections are methods that can be used to minimize these effects.

2.17.4 RFI

Radio Frequency Interference (RFI) is a general term frequently used to describe electromagnetic interference over a wide range of frequencies across the spectrum. RFI can be especially troublesome at low signal levels, but it may also affect high level measurements in extreme cases.

RFI can be caused by steady-state sources such as TV or radio broadcast signals, or it can result from impulse sources, as in the case of arcing in high voltage environments. In either case, the effect on instrument performance can be considerable, if enough of the unwanted signal is present. The effects of RFI can often be seen as an unusually large offset, or, in the case of impulse sources, sudden, erratic variations in the displayed reading.

RFI can be minimized by taking one (or more) of several precautions when operating the Model 619 in such environments. The most obvious method is to keep the instrument and experiment as far away from the RFI source as possible. Shielding the instrument, experiment, and test leads will often reduce RFI to an acceptable level. In extreme cases, a specially constructed screen room may be necessary to sufficiently attenuate the troublesome signal.

If all else fails, external filtering of the input signal path may be required. In some cases, a simple one-pole filter may be sufficient. In more difficult situations, multiple-pole notch or band-stop filters, tuned to the offending frequency range, may be required. Keep in mind, however, that such filtering may have other detrimental effects (such as increased response time) on the measurement.

2.17.5 Leakage Resistance Effects

At normal resistance levels, the effects of leakage resistance are seldom seen because any leakage resistance present is generally much higher than the resistance levels encountered in the circuit under test. At the high resistance levels of many Model 619 measurements, however, leakage resistance can have a detrimental effect on the measurement. Such leakage resistance can occur in the circuit under test (on PC boards, for example), in the connecting cable, or even at the electrometer input itself, especially if the input connector is not kept clean.

To see how leakage resistance can affect measurement accuracy, let us review the equivalent circuit in Figure 2-28. E_S and R_S are the source voltage and source resistance respectively. The leakage resistance is represented by R_L, while the voltage, as seen by the electrometer, is V_M.

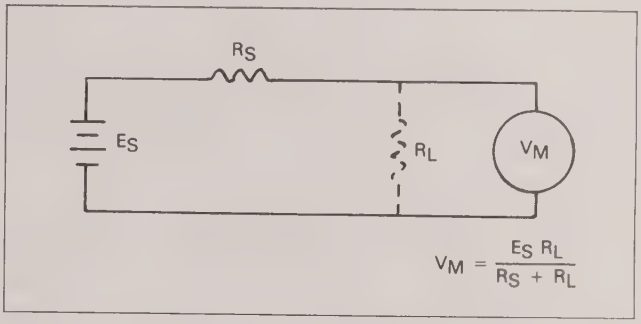


Figure 2-28. Leakage Resistance Effects

R_S and R_L form a voltage divider that attenuates the input signal in accordance with the formula:

$$V_M = \frac{E_S R_L}{R_S + R_L}$$

Thus, if R_L has a value of 100GΩ and R_S is 10GΩ, the actual voltage measured by the electrometer with 10V source would be:

$$V_M = \frac{10 \times 100G\Omega}{10G\Omega + 100G\Omega}$$

$$V_M = 9.09V$$

Thus, we see that the effects of leakage resistance can be substantial, resulting in an error of almost 10% in this case.

Certain steps can be taken to ensure that the effects of leakage resistance are minimal. The most obvious remedy to ensure that the leakage resistance itself is as high as possible. Use only good quality triaxial cable for signal connections, and make sure that the circuit under test and connectors are kept free of contamination.

Even with these steps, however, there is a limit as to how high the leakage resistance can be. In those cases, guarded input connections should be used, as described in paragraph 2.10.2.

2.17.6 Input Capacitance Effects

Virtually any circuit has at least some small amount of distributed capacitance that can slow down the response time of high-impedance measurements. Even if the circuit itself has minimal capacitance, cable or instrument input capacitance effects can be noticeable.

When E_S is first applied, the voltage across the capacitance (and thus, at the electrometer input) does not instantaneously rise to its final value. Instead, the capacitance charges exponentially in accordance with the following formula:

$$V_M = E_S\,(1 - e^{\frac{-t}{RC}})$$

Note that R_S is given in megohms, C is in microfarads, while t is in seconds.

Because of the charging of C_{IN}, the electrometer follows the exponential curve shown in Figure 2-29B. At the end of one time constant (R_SC_{IN}), the voltage will reach approximately 63% of its final value. At the end of two time constants ($2R_SC$), the voltage will reach about 86% of its final value, and so on. Generally, at least five time constants should be allowed for better than 1% accuracy.

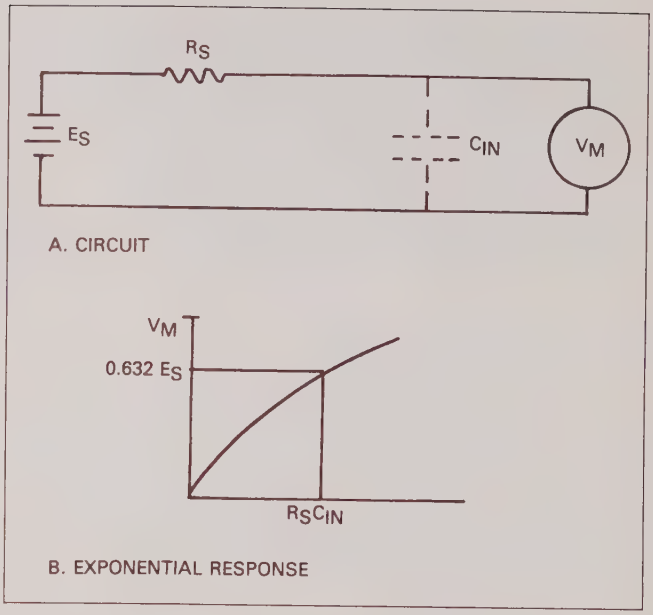


Figure 2-9. Input Capacitance Effects

The amount of time that must be allowed will, of course, depend on the relative values of R_S, and C_{IN}. For example, when measuring a voltage with a source resistance of 10GΩ with an input capacitance of 100pF, a time constant of one second results. Thus, at least five seconds must be allowed to achieve a better than 1% accuracy figure. Table 2-6 summarizes voltage values and percentage error values for ten different time constants ($\tau = R_SC_{IN}$).

Table 2-6. Voltage and Percent Error For Various Time Constants

Time*	V_M	%Error
τ	0.632 E_S	36%
2τ	0.86 E_S	14%
3τ	0.95 E_S	5%
4τ	0.982 E_S	1.8%
5τ	0.993 E_S	0.674%
6τ	0.9975 E_S	0.25%
7τ	0.999 E_S	0.09%
8τ	0.99966E_S	0.033%
9τ	0.9999 E_S	0.012%
10τ	0.99995E_S	0.005%

*$\tau = R_S C_{IN}$

The most obvious method to minimize the slowing effects of input capacitance is to minimize the amount of capacitance in the circuit. Using low capacitance cable and keeping the cable as short as possible are two ways to do so. However, there is a limit to the amount of capacitance reduction that can be achieved. In those cases, especially where high impedance levels are involved, guarded operation (see paragraph 2.10.2) may be necessary.

While input capacitance does increase rise-time, it can help to filter out some noise present at the input by effectively reducing electrometer bandwidth. If we assume that all input capacitance is lumped into a single element, the half-power (−3dB) point of the circuit in Figure 2-29 will be:

$$f_{-3dB} = \frac{1}{2\pi R_S C_{IN}}$$

Thus, if R_S has a value of 10MΩ, and C_{IN} has a value of 100pF, the half-power point will be 159Hz.

SECTION 3
IEEE-488 PROGRAMMING

3.1 INTRODUCTION

With the Model 6193 IEEE-488 interface installed, most Model 619 operating modes and functions can be controlled over the IEEE-488 bus. In addition, data and status can be obtained from the instrument.

This section contains general bus information as well as the necessary programming information and is divided into the following sections:

1. Introductory information pertaining to the IEEE-488 bus in general is located in paragraph 3.2 through 3.6.
2. Information necessary to connect the Model 619 to the IEEE-488 bus is contained in paragraphs 3.7 and 3.8.
3. General bus command programming is covered in paragraph 3.9.
4. Device-dependent command programming is described in paragraph 3.10. These are the most important commands associated with the Model 619 as they control most of the instrument functions.
5. Additional information necessary to use the Model 619 over the IEEE-488 bus is located in the remaining paragraphs.

3.2 BUS DESCRIPTION

The IEEE-488 bus, which is also frequently referred to as the GPIB (General Purpose Interface Bus), was designed as a parallel transfer medium to optimize data transfer without using an excessive number of bus lines. In keeping with this goal, the bus has only eight data lines that are used for both data and with most commands. Five bus management lines and three handshake lines round out the complement of bus signal lines.

A typical configuration for controlled operation is shown in Figure 3-1. The typical system will have at least one controller and one or more devices to which commands are given and, in most cases, from which data is received. Generally, there are three categories that describe device operation: controller, talker, and listener.

The controller does what its name implies: it controls other devices on the bus. A talker sends data (usually to the controller), while a listener receives data. Depending on the instrument, a particular device may be a talker only, a listener only, or both a talker and a listener.

There are two categories of controllers: system controller and basic controller. Both are able to control other instruments, but only the system controller has the absolute authority in the system. In a system with more than one controller, only one controller may be active at any given time. Certain protocol is used to pass control from one controller to another.

The IEEE-488 bus is limited to 15 devices, including the controller. Thus, any number of talkers and listeners up to that limit may be present on the bus at one time. Although several devices may be commanded to listen simultaneously, the bus can have only one active talker, or communications would be scrambled.

A device is placed in the talk or listen state by sending an appropriate talk or listen command. These talk and listen commands are derived from an instrument's primary address. The primary address may have any value between 0 and 30, and is generally set by rear panel DIP switches or programmed in from the front panel of the instrument. The actual listen address value sent out over the bus is obtained by ORing the primary address with $20. For example, if the primary address is 6 ($06), the actual listen address is $26 ($26 = $06 + $20). In a similar manner, the talk address is obtained by ORing the primary address value with $40. With the present example, the talk address derived from a primary address of 6 decimal would be $46 ($46 = $06 + $40).

The IEEE-488 standards also include another addressing mode called secondary adressing. Secondary addressing lie in the range of $60-$7F. Note, that many devices do not use secondary addressing. However, secondary addressing must be used with the Model 619 to send commands as well as to access instrument data. Secondary addressing is covered in more detail in paragraph 3.7.4, as well as in various other paragraphs in this section.

Once the device is properly addressed, appropriate bus transactions are set to take place. For example, if an instrument is addressed to talk, it will usually place its data byte on the bus one byte at a time. The listening device (frequently the controller) will then read this information.

3.3 IEEE-488 BUS LINES

The signal lines on the IEEE-488 bus are grouped into three different categories: data lines, management lines and handshake lines. The data lines handle bus data and commands,

while the management and handshake lines ensure that proper data transfer and bus operation takes place. Each bus line is active low, with approximately zero volts representing a logic 1 (true). The following paragraphs describe the purpose of these lines, which are shown in Figure 3-1.

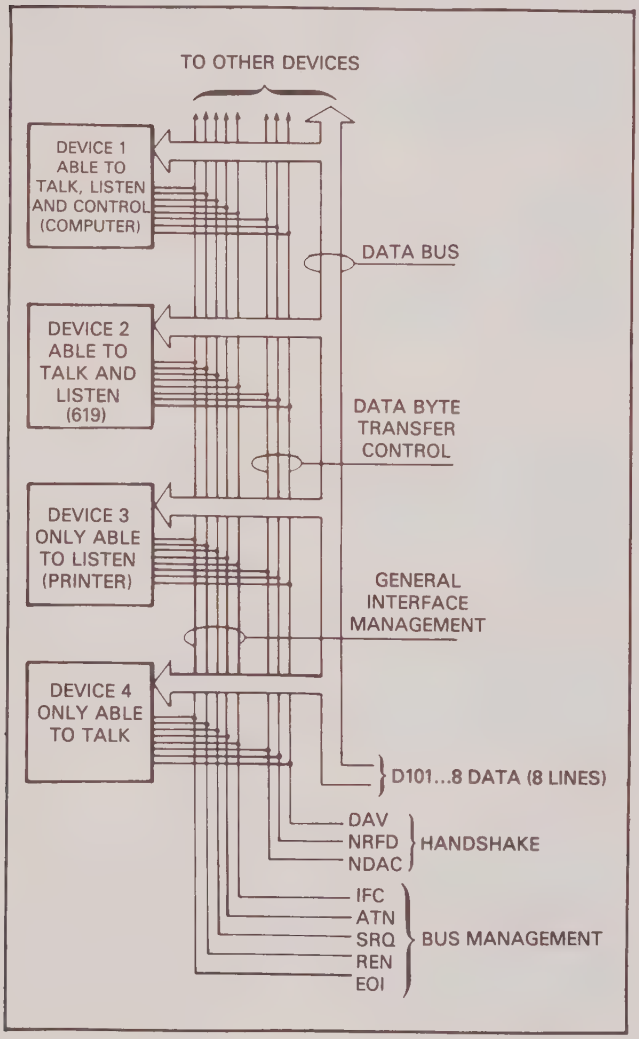


Figure 3-1. IEEE Bus Configuration

3.3.1 Data Lines

The IEEE-488 bus uses eight data lines that allow data to be transmitted and received in a bit-parallel, byte serial manner. These lines use the convention DIO1-DIO8 instead of the more common D0-D7. DIO1 is the least significant bit, while DIO8 is the most significant bit. The data lines are bidirectional (with most devices), and, as with the remaining lines, low is considered to be true.

3.3.2 Bus Management Lines

The five bus management lines help to ensure proper interface control and management. These lines are used to send the uniline commands that are described in paragraph 3.4.1.

ATN (Attention)—The ATN line is one of the more important management lines in that the state of this line determines how information on the data bus is to be interpreted.

IFC (Interface Clear)—As the name implies, the IFC line controls clearing of instruments from the bus.

REN (Remote Enable)—The REN line is used to place an instrument on the bus in the remote mode.

EOI (End or Identify)—The EOI line is usually used to mark the end of a multi-byte data transfer sequence.

SRQ (Service Request)—This line is used by devices when they require service from the controller.

3.3.3 Handshake Lines

The bus uses three handshake lines that operate in an interlocked sequence. This method ensures reliable data transmission regardless of the transfer rate. Generally, data transfer will occur at a rate determined by the slowest device on the bus.

One of the three handshake lines is controlled by the source (the talker sending information), while the remaining two lines are controlled by accepting devices (the listener or listeners receiving the information). The three handshake lines are:

DAV (Data Valid)—The source controls the state of the DAV line to indicate to any listening devices whether or not data bus information is valid.

NRFD (Not Ready For Data)—The acceptor controls the state of NRFD. It is used to signal to the transmitting device to hold off the byte transfer sequence.

NDAC (Not Data Accepted)—NDAC is also controlled by the accepting device.

The complete handshake sequence for one data byte is shown in Figure 3-2. Once data is placed on the data lines, the source checks to see that NRFD is high, indicating that all active devices are ready. At the same time, NDAC should be low from the previous byte transfer. If these conditions are not met, the source must wait until NDAC and NRFD have the correct status. If the source is a controller, NRFD and NDAC must be stable for at least 100nsec after ATN is set true. Because of the possibility of a bus hang up, many controllers have time-out routines that display messages in case the transfer sequence stops for any reason.

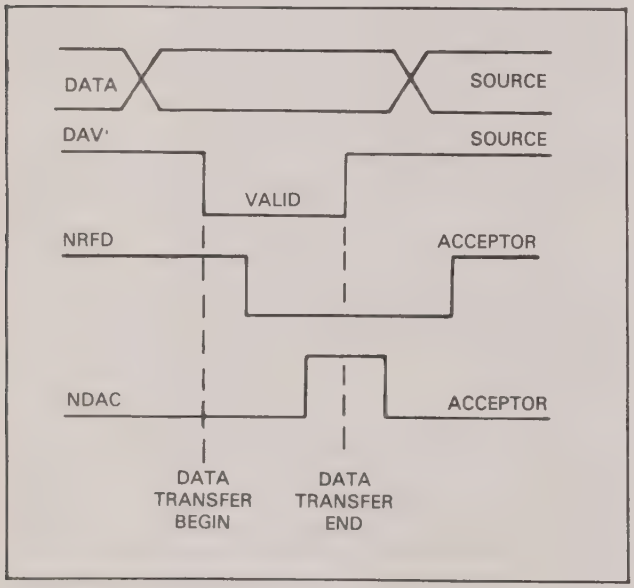


Figure 3-2. IEEE-488 Handshake Sequence

Once all NDAC and NRFD are properly set, the source sets DAV low, indicating to accepting devices that the byte on the data lines is now valid. NRFD will then go low, and NDAC will go high once all devices have accepted the data. Each device will release NDAC at its own rate, but NDAC will not be released to go high until all devices have accepted the data byte.

Once NDAC goes high, the source then sets DAV high to indicate that the data byte is no longer valid. NDAC is returned to its low state, and NRFD is released by each device at its own rate, until NRFD goes high when the slowest device is ready, and the bus is set to repeat the process with the next data byte.

The sequence just described is used to transfer data, talk, listen and secondary address, as well as multiline commands.

The state of the ATN line determines whether the data bus contains data, addresses, or commands as described in the following paragraph.

3.4 BUS COMMANDS

While hardware aspects of the bus are essential, the interface would have minimal capabilities without appropriate commands to control communications among the various devices on the bus. This paragraph briefly describes the purposes of the various device commands, which are grouped into the following three general categories:

Uniline Commands—Sent by setting the corresponding bus line true.

Multiline Commands—General bus commands which are sent over the data lines with ATN true (low).

Device-dependent Commands—Special commands whose meanings depend on device configuration; sent over the data lines with ATN high (false).

These bus commands and their general purposes are summarized in Table 3-1.

3.4.1 Uniline Commands

ATN, IFC and REN are asserted only by the controller. SRQ is asserted by an external device. EOI may be asserted either by the controller or other devices depending on the direction of data transfer. The following is a description of each command. Each command is sent by setting the corresponding bus line true.

REN (Remote Enable)—REN is sent to set up instrument on the bus for remote operation. Generally, REN should be sent before attempting to program instruments over the bus.

EOI (End Or Identify)—EOI is used to positively identify the last byte in a multi-byte transfer sequence, thus allowing data words of various lengths to be transmitted easily.

IFC (Interface Clear)—IFC is used to clear the interface and return all devices to the talker and listener idle states.

ATN (Attention)—The controller sends ATN while transmitting addresses or multiline commands.

Table 3-1. IEEE-488 Bus Command Summary

Command Type	Command	State of ATN Line*	Comments
Uniline	REN (Remote Enable)	X	Set up for remote operation.
	EOI	X	Marks end of transmission.
	IFC (Interface Clear)	X	Clears Interface
	ATN (Attention)	Low	Defines data bus contents.
	SRQ	X	Controlled by external device.
Multiline			
Universal	LLO (Local Lockout)	Low	Locks out front panel controls.
	DCL (Device Clear)	Low	Returns device to default conditions.
	SPE (Serial Poll Enable)	Low	Enables serial polling.
	SPD (Serial Poll Disable)	Low	Disables serial polling.
Addressed	SDC (Selective Device Clear)	Low	Returns unit to default conditions.
	GTL (Go To Local)	Low	Sends go to local.
	GET (Group Execute Trigger)	Low	Triggers device for reading.
Unaddressed	UNL (Unlisten)	Low	Removes all listeners from bus.
	UNT (Untalk)	Low	Removes any talkers from bus.
Device-dependent**		High	Programs Model 619 for various modes.

*X = Don't Care.
**See paragraph 3.10 for complete description.

SRQ (Service Request)—SRQ is asserted by a device when it requires service from a controller.

3.4.2 Universal Commands

Universal commands are those multiline commands that require no addressing. All devices equipped to implement such commands will do so simultaneously when the command is transmitted. As with all multiline commands, these commands are transmitted with ATN true.

LLO (Local Lockout)—LLO is sent to instruments to lock out their front panel controls.

DCL (Device Clear)—DCL is used to return instruments to some default state. Usually, instruments return to their power-up conditions.

SPE (Serial Poll Enable)—SPE is the first step in the serial polling sequence, which is used to determine which device has requested service.

SPD (Serial Poll Disable)—SPD is used by the controller to remove all devices on the bus from the serial poll mode and is generally the last command in the serial polling sequence.

3.4.3 Addressed Commands

Addressed commands are multiline commands that must be preceded by the device listen address before that instrument will respond to the command in question. Note that only the addressed device will respond to these commands.

SDC (Selective Device Clear)—The SDC command performs essentially the same function as the DCL command except that only the addressed device responds. Generally, instruments return to their power-up default conditions when responding to the SDC command.

GTL (Go To Local)—The GTL command is used to remove instruments from the remote mode. With some instruments, GTL also unlocks front panel controls if they were previously locked out with the LLO command.

GET (Group Execute Trigger)—The GET command is used to trigger devices to perform a specific action that depends on device configuration (for example, take a reading). Although GET is an addressed command, many devices respond to GET without addressing.

3.4.4 Unaddress Commands

The two unaddress commands are used by the controller to remove any talkers or listeners from the bus. ATN is true when these commands are asserted.

UNL (Unlisten)—Listeners are placed in the listener idle state by the UNL command.

UNT (Untalk)—Any previously commanded talkers will be placed in the talker idle state by the UNT command.

3.4.5 Device-Dependent Commands

The meaning of the device-dependent commands will depend on the configuration of the instrument. Generally, these commands are sent as one or more ASCII characters that tell the device to perform a specific function. For example, the command sequence F0X is used to place the Model 619 in the volts mode. The IEEE-488 bus actually treats these commands as data in that ATN is false when the commands are transmitted.

3.5 COMMAND CODES

Each multiline command is given a unique code that is transmitted over the bus as 7 bit ASCII data. This section briefly explains the code groups, which are summarized in Figure 3-3.

Addressed Command Group (ACG)—Addressed commands and corresponding ASCII codes are listed in columns 0(A) and 0(B).

Universal Command Group (UCG)—Universal commands and values are listed in columns 1(A) nad 1(B).

Listen Address Group (LAG)—Columns 2(A) through 3(B) list codes for commands in this address group. For example, if the primary address of the instrument is 27, the LAG byte will be an ASCII left bracket.

Talk Address Group (TAG)—TAG primary address values and corresponding ASCII characters are listed in columns 4(A) through 5(B).

The preceding address groups are combined together to form the Primary Command Group (PCG). The bus also has another group of commands, called the Secondary Command Group (SCG). These commands are used with the Model 619 to select the channel, obtain status, and as part of the serial polling sequence.

Note that these commands are normally transmitted with the 7 bit code listed in Figure 3-3. For many devices, the condition of DIO8 is unimportant. However, many devices may require that DIO8 has a value of logic 0 (high) to properly send commands.

Hexadecimal and decimal values for each of the commands or command groups are listed in Table 3-2. Each value assumes that DIO8 has a value of 0.

Table 3-2. Hexadecimal and Decimal Command Codes

Command	Hex Value	Decimal Value
GTL	01	1
SDC	04	4
GET	08	8
LLO	11	17
DCL	14	20
SPE	18	24
SPD	19	25
LAG	20-3F	32-63
TAG	40-5F	64-95
SCG	60-7F	96-127
UNL	3F	63
UNT	5F	95

3.6 COMMAND SEQUENCES

The proper command sequence must be sent to the instrument before it will respond as intended. Universal commands, such as LLO and DCL, require only that ATN be set low when sending the command. Other commands require

Bits D_7 D_6 D_5 D_4					X 0 0 0		X 0 0 1		X 0 1 0		X 0 1 1		X 1 0		X 1 0 1		X 1 1 0		X 1 1 1	
D_3	D_2	D_1	D_0	COLUMN → ROW↓	0 (A)	0 (B)	1 (A)	1 (B)	2 (A)	2 (B)	3 (A)	3 (B)	4 (A)	4 (B)	5 (A)	5 (B)	6 (A)	6 (B)	7 (A)	7 (B)
0	0	0	0	0	NUL		DLE		SP	0	0	16	@	0	P	16			p	
0	0	0	1	1	SOH	GTL	DC1	LLO	!	1	1	17	A	1	Q	17	a		q	
0	0	1	0	2	STX		DC2		"	2	2	18	B	2	R	18	b		r	
0	0	1	1	3	ETX		DC3		#	3	3	19	C		S	19	c		s	
0	1	0	0	4	EOT	SDC	DC4	DCL	$	4	4	20	D	4	T	20	d		t	
0	1	0	0	5	ENQ	PPC*	NAK	PPU*	%	5	5	21	E	5	U	21	e		u	
0	1	1	0	6	ACK		SYN		&	6	6	22	F	6	V	22	f		v	
0	1	1	1	7	BEL		ETB		'	7	7	23	G	7	W	23	g		w	
1	0	0	0	8	BS	GET	CAN	SPE	(	8	8	24	H	8	X	24	h		x	
1	0	0	1	9	HT	TCT*	EM	SPD	)	9	9	25	I	9	Y	25	i		y	
1	0	1	0	10	LF		SUB		*	10		26	J	10	Z	26	j		z	
1	0	1	1	11	VT		ESC		+	11	;	27	K	11	[	27	k		{	
1	1	0	0	12	FF		FS		,	12	<	28	L	12	\	28	l		:	
1	1	0	1	13	CR		GS		–	13	=	29	M	13	]	29	m		}	
1	1	1	0	14	SO		RS		.	14	>	30	N	14	^	30	n		~	
1	1	1	1	15	SI		US		/	15	?	UNL	O	15	_	UNT	o		DEL	

ADDRESSED COMMAND GROUP (ACG)

UNIVERSAL COMMAND GROUP (UCG)

LISTEN ADDRESS GROUP (LAG)

TALK ADDRESS GROUP (TAG)

PRIMARY COMMAND GROUP (PCG)

SECONDARY COMMAND GROUP (SDC)

*PPC (Parallel Poll Configure), PPU (Parallel Poll Unconfigure), and TCT (Take Control) not implemented by Model 619

NOTE: D_0 = DIO1...D_7 = DIO8
X = Don't Care

Figure 3-3. Command Groups

that the instrument be properly addressed to listen first. This section briefly describes the bus sequence for several types of commands.

3.6.1 Addressed Command Sequence

Before a device will respond to one of these commands, it must receive a LAG command derived from its primary address. Table 3-3 shows a typical sequence for the SDC command; the example assumes that a primary address of 6 (factory setting), and a secondary address of 1 (channel A), are being used.

Table 3-3. Typical Addressed Command Sequence

Step	Command	ATN State	Data Bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	&	26	38
3	SCG**	Stays low	a	61	97
4	SDC	Stays low	EOT	04	4

*Assumes primary address = 6.

**Secondary address to access channel A.

Note that an UNL command is generally sent before the LAG, SCG and SDC sequence. This is usually done to remove all other listeners from the bus so that the desired device responds to the command.

3.6.2 Universal Command Sequence

Universal commands are sent by setting ATN low and then placing the command byte on the data bus. ATN would then remain low during the period the command is transmitted. For example, if the LLO command were to be sent, both ATN and LLO would be asserted simultaneously.

3.6.3 Device-Dependent Command Sequence

Device-dependent commands are transmitted with ATN false. However, a device must be addressed to listen before these commands are transmitted. Table 3-4 shows the byte sequence for a typical Model 619 command (F0X), which sets the instrument to the volts function.

Table 3-4. Typical Device-Dependent Command Sequence

Step	Command	ATN State	Data Bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	&	26	38
3	SCG**	Stays low	a	61	97
4	Data	Set high	F	46	70
5	Data	Stays high	0	30	48
6	Data	Stays high	X	58	88

*Assumes primary address = 6.

**Secondary address to access channel A.

3.7 OPERATIONAL CONSIDERATIONS

Before the Model 619 can be operated over the IEEE-488 bus, it must first be connected to the bus with a suitable cable. Also, the primary address must be programmed to the correct value, and the correct secondary address must be used as described in the following paragraphs.

3.7.1 Typical Controlled Systems

System configurations are many and varied and will depend on the application. To obtain as much versatility as possible, the IEEE-488 bus was designed so that additional instrumentation could be easily added. Because of this versatility, system complexity can range from the very simple to extremely complex.

Figure 3-4 shows two possible system configurations. Figure 3-4(a) shows the simplest possible controlled system. The controller is used to send commands to the instrument, which sends data back to the controller.

The system in Figure 3-4(b) is somewhat more complex in that additional instruments are used. Depending on programming, all data may be routed through the controller, or it may be sent directly from one instrument to another.

In very complex applications, a larger computer could be used. Tape drives or disks could be used to store any data generated by the instruments.

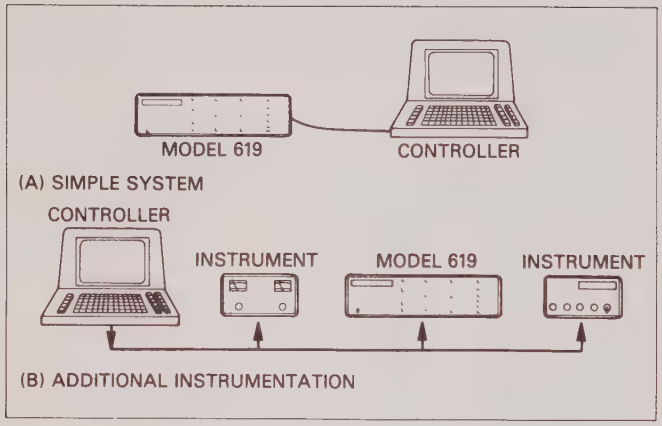


Figure 3-4. System Types

3.7.2 Bus Connections

The Model 619 is to be connected to the IEEE-488 bus through a cable equipped with standard IEEE-488 connectors, an example of which is shown in Figure 3-5. The connector is designed to be stacked to allow a number of parallel connections. Two screws are located on each connector to ensure that connections remain secure. Current standards call for metric threads, as identified by dark colored screws. Earlier versions had different screws, which are silver colored. Do not attempt to use these type of connectors with the Model 619, which is designed for metric threads.

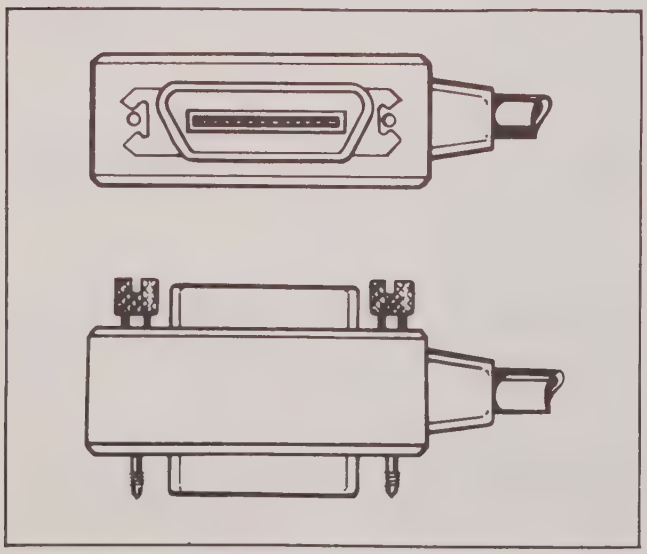


Figure 3-5. IEEE-488 Connector

A typical connecting scheme for the bus is shown in Figure 3-6. Each cable normally has the standard connector on each end. These connectors are designed to be stacked to allow a number of parallel connections on one instrument.

NOTE

To avoid possible damage, it is recommended that you stack no more than three connectors on any one instrument.

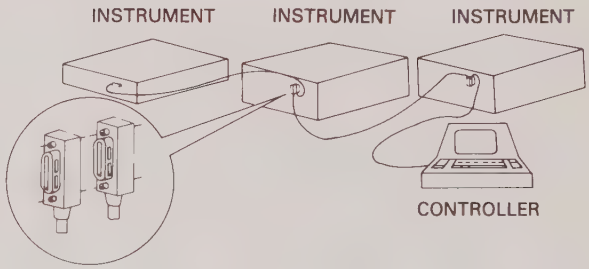


Figure 3-6. IEEE-488 Connections

Connect the Model 619 to the cable as follows:

1. Line up the connector on the cable with the connector on the rear panel of the instrument. See Figure 3-7 for connector location.
2. Tighten the screws securely, but do not overtighten them.
3. Add additional connectors from other instruments, as required.
4. Make sure the other end of the cable is properly connected to the controller. Some controllers have an IEEE-488 type connector, while others do not. Consult the instruction manual for your controller for the proper connecting method.

NOTE

The IEEE-488 bus is limited to a maximum of 15 devices, including the controller. Also, the maximum cable length is limited to 20 meters, or 2 meters times the number of devices, which ever is less. Failure to heed these limits may result in erratic bus operation.

Custom cables may be constructed by using the information in Table 3-5 and Figure 3-8. Table 3-5 lists the contact assignments for the various bus lines, while Figure 3-8 shows contact assignments.

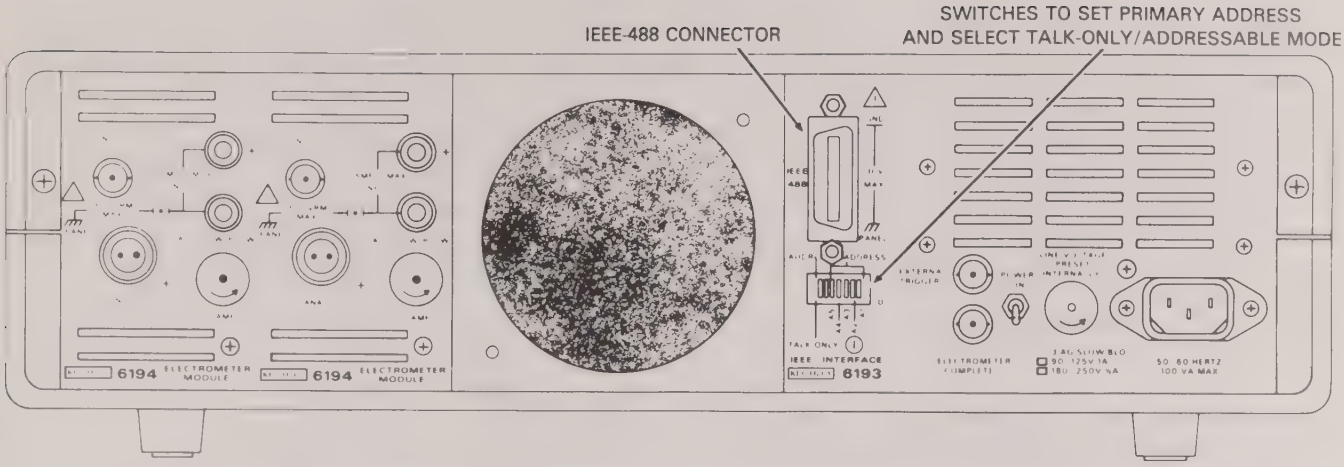


Figure 3-7. Locations for IEEE-488 Connector and Programming Switches

Table 3-5. IEEE Contact Designations

Contact Number	IEEE-488 Designation	Type
1	DIO1	Data
2	DIO2	Data
3	DIO3	Data
4	DIO4	Data
5	EOI (24)*	Management
6	DAV	Handshake
7	NRFD	Handshake
8	NDAC	Handshake
9	IFC	Management
10	SRQ	Management
11	ATN	Management
12	SHIELD	Ground
13	DIO5	Data
14	DIO6	Data
15	DIO7	Data
16	DIO8	Data
17	REN (24)*	Management
18	Gnd, (6)*	Ground
19	Gnd, (7)*	Ground
20	Gnd, (8)*	Ground
21	Gnd, (9)*	Ground
22	Gnd, (10)*	Ground
23	Gnd, (11)*	Ground
24	Gnd, LOGIC	Ground

*Number in parenthesis refer to signal ground return of reference contact number. EOI and REN signal lines return on contact 24.

CAUTION

The voltage between IEEE-488 common and chassis ground must not exceed 30V or instrument damage may occur.

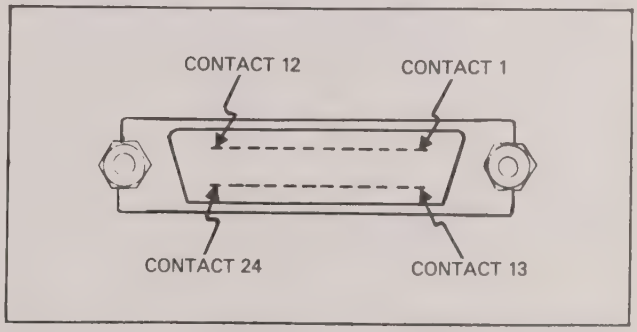


Figure 3-8. Contact Assignments

3.7.3 Primary Address Settings

The Model 619 must receive a listen command before it will respond to addressed commands. Similarly the unit must receive a talk command before it will transmit its data (the unit must also receive an appropriate secondary address as described in paragraph 3.7.4). These talk and listen commands are derived from the instrument's primary address, which is set by DIP switches located on the rear panel (see Figure 3-7). One of these switches also controls talk only/addressable mode of operation. The unit must be in the addressable mode to respond to controller commands.

The Model 619 is shipped from the factory with a primary address of 6, but the address may be set to any desired value between 0 and 30 by setting the address switches to the correct positions (see Table 3-6). Since each device on the bus must have a unique primary address, you must be careful not to use the same primary address for two devices. Keep in mind that most controllers also use a primary address. Most frequently, controller addresses are set to 0 or 21, but you should consult the controller's instruction manual for details. Whatever address you use, it must correspond with the value specified as part of the controller's programming language. Note that primary address 31 is reserved for UNL and UNT, and must not be used.

NOTE

The address switches are read by the instrument only during power up. Thus the instrument must be momentarily turned off before it will recognize an address change.

3.7.4 Secondary Addressing

In addition to the primary address, a secondary address must be sent to the instrument before it will respond to addressed commands or transmit its data. Table 3-7 summarizes secondary addresses to be used with the instrument. Three forms are given in the table: the absolute secondary address value (such as 1 or 2), the hexadecimal value of the byte actually sent over the bus, and the ASCII equivalent. You'll note that the actual byte sent over the bus is derived by ORing the secondary address with $60. This method is analogous to that used to derive talk and listen addresses from the primary address (the listen address is derived by ORing the primary address with $20, and the talk address is derived by ORing the primary address with $40).

Secondary addressing is used with the Model 619 to control the following aspects of bus operation:

1. Channel selection: The secondary address selects the channel controlled by device-dependent commands, and from which channel data is obtained. A secondary address of 1 ($61) selects channel A, while a secondary address of 2 ($62) is used to select channel B. Channel B is available only if an optional Model 6194 Electrometer Module is installed in the channel B location.
2. Serial polling: A secondary address of 6 ($66) must be sent as part of the serial polling sequence. Serial polling is covered in detail in paragraphs 3.9 and 3.10.10.
3. Machine status: Status of various operating modes for channels A and B may be obtained by sending secondary addresses of 3 ($63) and 4($64) respectively. See paragraph 3.11 for more details.

Table 3-6. Primary Address Settings

Primary Address	Switch Position				
	A5	A4	A3	A2	A1
0	0	0	0	0	0
1	0	0	0	0	1
2	0	0	0	1	0
3	0	0	0	1	1
4	0	0	1	0	0
5	0	0	1	0	1
6*	0	0	1	1	0
7	0	0	1	1	1
8	0	1	0	0	0
9	0	1	0	0	1
10	0	1	0	1	0
11	0	1	0	1	1
12	0	1	1	0	0
13	0	1	1	0	1
14	0	1	1	1	0
15	0	1	1	1	1
16	1	0	0	0	0
17	1	0	0	0	1
18	1	0	0	1	0
19	1	0	0	1	1
20	1	0	1	0	0
21	1	0	1	0	1
22	1	0	1	1	0
23	1	0	1	1	1
24	1	1	0	0	0
25	1	1	0	0	1
26	1	1	0	1	0
27	1	1	0	1	1
28	1	1	1	0	0
29	1	1	1	0	1
30	1	1	1	1	0

*Factory default setting.

NOTE: Address 31 is reserved for UNL and UNT commands and must not be used.

Table 3-7. Secondary Addresses

Function	Hexadecimal		
	Address	Value	ASCII
Channel A (Listen or Talk)	1	$61	a
Channel B (Listen or Talk)	2	$62	b
Channel A Status	3	$63	c
Channel B Status	4	$64	d
Serial Polling	6	$66	f

3.7.5 Talk Only Mode

The Model 619 may be placed in the talk-only mode and be used with a listen-only device such as a printer. In this mode, the instrument will ignore commands given over the bus and merely output data as requested by the listening device.

To place the instrument in the talk-only mode, place the TALK ONLY/ADDR DIP switch (see Figure 3-7) in the TALK ONLY position. Data formats for the various operating functions when in the talk-only mode are summarized in Table 3-8.

Table 3-8. Talk-Only Mode Data Formats

Function	Data
Volts	*NDCV ±1.23456±09 (CR LF)
Amps	NDCA ±1.23456±09 (CR LF)
Ohms	NOHM ±1.23456±09 (CR LF)
Ratio**	NRAT ±1.23456±09 (CR LF)
Difference**	NDIF ±1.23456±09 (CR LF)

*N = Normal Reading
O = Overflow Reading
**Available in "Talk Only" operation only.

NOTES:

1. The primary address and TALK ONLY/ADDR switch positions are read only upon power up. Thus, power to the instrument must be cycled after a switch position is change before the instrument will recognize the new switch conditions.
2. The ratio and difference features are available only in the talk-only mode.
3. Data output in the talk-only mode may be controlled on a one-shot basis with the RATIO A/B or DIFFERENCE A/B buttons. To use the instrument in this manner, an internal switch must be sent to the appropriate trigger mode (see Section 7), and the instrument must be placed in the one-shot mode by pressing the RESOLUTION button. Once in this mode, the instrument will output one reading over the bus once each time the RATIO A/B or DIFFERENCE button is pressed.

3.8 CONTROLLER PROGRAMMING

There are a number of IEEE-488 controllers available, each of which has its own programming language. This section contains a discussion on programming languages for two typical controllers: the HP-85 and the IBM-PC interfaced to the bus through a Keithley Model 8573 IEEE-488 interface.

3.8.1 Controller Handler Software

Before a specific controller can be used over the IEEE-488 bus, it must have IEEE-488 handler software installed. With some controllers, the software is located in ROM, and no software initialization is required on the part of the user. With other controllers, software must be loaded from disk or tape and be properly initialized. With the HP-85, for example, an additional I/O ROM that handles interface functions must be installed. With the Keithley Model 8573 interface for the IBM-PC, software must be installed and configured from a diskette.

Other small computers that can be used as IEEE-488 controllers may have limited capabilities. With some, interface programming functions may depend on the interface being used. Often little software "tricks" are required to obtain the desired results.

From the preceding discussion, the message is clear: make sure the proper software is being used with the interface. Often, the user may incorrectly suspect that the hardware is causing a problem when it was the software all along.

3.8.2 Interface BASIC Programming Statements

Many of the programming instructions covered in this section use examples written with Hewlett Packard Model 85 BASIC and Model 8573 Interface statements. These computers and interfaces were chosen for these examples because of their versatility in controlling the IEEE-488 bus. This section covers those HP-85 and Model 8573 statements that are essential to Model 619 operation.

Table 3-9. BASIC Statements Necessary to Send Bus Commands

Operation	HP-85 Statement(s)	Model 8573 Statement*
Send string to 619.	SEND 7; MTA LISTEN 6 SCG 1 @ OUTPUT 7;A$	CALL IBWRT(M619%,CMD$)
Obtain string from 619.	SEND 7;MLA TALK 6 SCG 1 @ ENTER 7;A$	CALL IBRD(M619%,RD$)
Send GTL to 619.	SEND 7;LISTEN 6 SCG 1 CMD 1	CALL IBLOC(M619%)
Send SDC to 619.	SEND 7;LISTEN 6 SCG 1 CMD 4	CALL IBCLR(M619%)
Send DCL to all devices.	CLEAR 7	CMD$ = CHR$(&H14):CALL IBCMD(BRD0%,CMD$)
Send remote enable.	REMOTE 7	V% = 1:CALL IBSRE (BRD0%,V%)
Cancel remote enable.	LOCAL 7	V% = 0:CALL IBSRE (BRD0%,V%)
Serial Poll 619.	SEND 7;MLA TALK 6 SCG 6 @ S = SPOLL(7)	CALL IBRSP(M619%,SB%)
Send local lockout.	LOCAL LOCKOUT 7	CMD$ = &H11:CALL IBCMD (BRD0%,CMD$)
Send GET	TRIGGER 7	CALL IBTRG(M617%)
Send IFC	ABORTIO 7	CALL IBSIC(BRD0%)

*Model 8573 statements assume that software has previously been configured for correct primary and secondary address. Secondary addresses for channel, addressed command and serial polling access differ, as described in text.

A partial list of HP-85 and Model 8573 statements is shown in Table 3-9. Many HP-85 statements have an argument that must be specified as part of the statement.

For example, the statement REMOTE 7 sets the REN line true. The value 7 is the interface select code, which is set to that value at the factory. If a different interface select code is used, programming statements must be modified accordingly.

All statements in Table 3-9 associated with commands requiring addressing use the SEND statement because the HP-85 has no convenient method to send secondary addresses. In the SEND parameter list, the MTA (My Talk Address) and MLA (My Listen Address) parameters are used by the computer to address its own interface. The TALK 6 or LISTEN 6 commands address the Model 619 to talk or listen respectively. The SCG command is used to send an appropriate secondary address to the Model 619. To select the appropriate channel, an SCG value of 1 (channel A) or 2 (channel B) will be used, as required. To obtain machine status, a value of 3 (channel A) or 4 (Channel B) is necessary, while an SCG parameter of 6 is used as part of the serial polling sequence.

Even with general addressed commands, some form of secondary addressing must be used. For the SDC and GTL commands, any secondary address in the range of 0-31 may be used. Note that since secondary addressing is necessary to send these commands, the SEND statement is used for these commands as well. The CMD parameter associated with the SEND statement is used to transmit the actual command byte to the instrument.

The Model 8573 statements, which are also listed in Table 3-9, take on a somewhat different form. Each of these statements uses the IBM BASIC CALL statement, with various variables passed as shown in the table. The command words, such as IBCLR (Interface Bus Clear) and IBSRE (Interface Bus Send Remote Enable), are, in fact, BASIC variables themselves, which must be initialized at the start of each BASIC program. In addition, you must remember not to use these keywords for any other purpose in your BASIC program.

Since the Model 619 requires the use of secondary addressing with addressed commands, you must make appropriate modifications to the Model 8573 software. Either permanently modify the configuration file, or use the IBSAD statement to send appropriate secondary addresses. Consult the Model 8573 Instruction Manual for details.

Before using the Model 8573 examples throughout this section, you must configure the software by using the procedure below. Note that the binary handler file called GPIB.COM and the system configuration file called CONFIG.SYS must be present on the DOS boot disk, as described in the Model 8573 Instruction Manual.

1. Boot up your system in the usual manner and enter BASICA.
2. Place the Model 8573 software disk into the default drive and load the program called "DECL.BAS". Modify the program by changing the XXXXX values in lines 1 and 2 to 16000.
3. Add the following lines to the declaration file:

```
 7 NA$="GPIB0":CALL IBFIND(NA$,BRD0%)
 8 NA$="DEV0":CALL IBFIND(NA$,M619%)
 9 V%=6:CALL IBPAD(M619%,V%)
10 V% = &H61:CALL IBSAD(M619%,V%)
```

   (For channel B, charge the V% variable to &H62).
4. Now save the modified declaration file for future use. Remember that you must load and run this short program before using the Model 8573 programming examples throughout this section. Also, do not use the BASIC CLEAR or new commands after running this program.

3.8.3 IEEE Command Groups

Command groups supported by the Model 619 are summarized in Table 3-10. Device-dependent commands, which are not covered in the table, are covered separately in paragraph 3.10.

3.9 GENERAL BUS COMMAND PROGRAMMING

General bus commands are those commands that have the same general meaning regardless of the instrument. Commands supported by the Model 619 are listed in Table 3-11, which also lists BASIC statements necessary to sent the commands. For addressed commands, a primary address of 6 and a secondary address of 1 are assumed. With Model 8573 examples, the modified declaration file must be run first, as discussed in paragraph 3.8.2.

3.9.1 REN (Remote Enable)

The remote enable command is sent to the Model 619 by the controller to set up the instrument for remote operation. Generally, the instrument should be placed in the remote mode before you attempt to program it over the bus. Simply setting REN true will not actually place the instrument in the remote mode. Instead the instrument must be addressed to listen after setting REN true before it will go into remote.

To place the Model 619 in the remote mode, the controller must perform the following sequence:

1. Set the REN line true.
2. Address the Model 619 to listen.

Table 3-10. IEEE Command Groups

HANDSHAKE COMMAND GROUP	
	DAC = DATA ACCEPTED
	RFD = READY FOR DATA
	DAV = DATA VALID
UNIVERSAL COMMAND GROUP	
	ATN = ATTENTION
	DCL = DEVICE CLEAR
	IFC = INTERFACE CLEAR
	LLO = LOCAL LOCKOUT
	REN = REMOTE ENABLE
	SPD = SERIAL POLL DISABLE
	SPE = SERIAL POLL ENABLE
ADDRESS COMMAND GROUP	
LISTEN:	LAG = LISTEN ADDRESS GROUP
	MLA = MY LISTEN ADDRESS
	UNL = UNLISTEN
TALK:	TAG = TALK ADDRESS GROUP
	MTA = MY TALK ADDRESS
	UNT = UNTALK
	OTA = OTHER TALK ADDRESS
ADDRESSED COMMAND GROUP	
	ACG = ADDRESSED COMMAND GROUP
	GET = GROUP EXECUTE TRIGGER
	GTL = GO TO LOCAL
	SDC = SELECTIVE DEVICE CLEAR
STATUS COMMAND GROUP	
	RQS = REQUEST SERVICE
	SRQ = SERIAL POLL REQUEST
	STB = STATUS BYTE
	EOI = END

3. Send an appropriate secondary address (1 or 2 for channel A or B).

HP-85 Programming Example—This sequence is automatically performed by the HP-85 when the following is typed into the keyboard.

```
REMOTE 7 (END LINE)
SEND 7; LISTEN 6 SCG 1 (END LINE)
```

After the sequence, the Model 619 will be in the remote mode, as indicated by the REMOTE light. If not, check to see that the instrument is set to the proper primary address (6), and check to see that the bus connections are properly made.

Model 8573 Programming Example—To place the Model 619 into the remote mode, type the following lines into the computer.

Table 3-11. General Bus Commands and Associated BASIC Statements

Command	HP-85 Statement	Model 8573 Statement	Affect On Model 619
REN	REMOTE 7	V% = 1:CALL IBSRE(BRD0%,V%)	Goes into remote when next addressed.
IFC	ABORTIO 7	CALL IBSIC(BRD0%)	Goes into talker and listener idle state.
LLO	LOCAL LOCKOUT 7	CMD$ = CHR$(&H11):CALL IBCMD (M619%,CMD$)	Front panel controls locked out.
GTL	SEND 7;LISTEN 6 SCG CMD 1	CALL IBLOC(M619%)	Cancels remote.
DCL	CLEAR 7	CMD$ = CHR$(&H14):CALL IBCMD (M619%,CMD$)	Returns to default conditions.
SDC	SEND 7;LISTEN 6 SCG 1 CMD 4	CALL IBCLR(M619%)	Returns to default conditions.
GET	TRIGGER 7	CALL IBTRG(M619%)	Triggers reading in T2 and T3 modes.
	LOCAL 7	V% = 0:CALL IBSRE(BRD0%,V%)	Cancels remote, permanently cancels LLO.

V% = 1:CALL IBSRE(BRD0%,V%) (return)
CMD$ = "X":CALL IBWRT(M619%,CMD$) (return)

The instrument will go into the remote mode when the return key is pressed the second time.

3.9.2 IFC (Interface Clear)

The IFC command is sent by the controller to place the Model 619 in the local, talker and listener idle states. The unit will respond to the IFC command by cancelling front panel TALK or LISTEN lights, if the instrument was previously placed in one of these modes.

To send the IFC command, the controller need only set the IFC line true for a minimum of 100μsec.

HP-85 Programming Example—Before demonstrating the IFC command, turn on the LISTEN indicator with the following statements:

REMOTE 7 (END LINE)
SEND 7; MTA LISTEN 6 SCG 1 (END LINE)
OUTPUT 7; "X" (END LINE)

At this point, the REMOTE and LISTEN lights should be on. The IFC command can be sent by typing in the following statement into the HP-85:

ABORTIO 7 (END LINE)

After the END LINE key is pressed, the LISTEN light will turn off, indicating that the instrument has gone into the listener idle state.

Model 8573 Programming Example—To send IFC, enter the following statement into the IBM-PC:

CALL IBSIC(BRD0%) (return)

3.9.3 LLO (Local Lockout)

The LLO command is used to remove the instrument from the local operating mode. After the unit receives LLO, all its front panel controls except POWER will be inoperative. The instrument must be in remote to respond to LLO. REN must be set false to cancel LLO. If LLO is sent with REN true but while the instrument is not in remote, LLO will take effect when the unit goes into remote.

To send the LLO command, the controller must perform the following steps:

1. Set ATN true.
2. Place the LLO command on the data bus.

HP-85 Programming Example—The LLO command is sent by using the following HP-85 statements:

```
REMOTE 7 (END LINE)
SEND 7; LISTEN 6 SCG 1 (END LINE)
LOCAL LOCKOUT 7 (END LINE)
```

After the third statement is entered, the instrument's front panel controls will be locked out (see paragraph 3.9.4 for methods to cancel LLO).

Model 8573 Programming Example—To send the LLO command from the IBM-PC, type in the following statements:

```
V%=1: CALL IBSRE (BRD0%,V%) (return)
CMD$="X": CALL IBWRT(M619%,CMD$) (return)
CMD$=CHR$(&H11):CALL  IBCMD(BRD0%,CMD$)
(return)
```

After the return key is pressed, Model 619 front panel controls will be locked out.

3.9.4 GTL (Go To Local) and Local

The GTL command is used to take the instrument out of the remote mode. GTL also temporarily cancels LLO. To permanently cancel LLO, set REN false.

To send GTL, the controller must perform the following sequence.

1. Set ATN true.
2. Address the Model 619 to listen.
3. Send an appropriate secondary address.
4. Place the GTL command on the bus.

With GTL any valid secondary address (0-31) may be used.

HP-85 Programming Example—Place the instrument in the remote mode with the following statments:

```
REMOTE 7 (END LINE)
SEND 7; LISTEN 6 SCG 1 (END LINE)
```

Now send GTL with the following statement:

```
SEND 7; LISTEN 6 SCG 1 CMD 1 (END LINE)
```

When the END LINE key is pressed, the front panel REMOTE indicator goes off, and the instrument goes into the local mode.

To permanently cancel LLO, send the following

```
LOCAL 7 (END LINE)
```

Model 8573 Programming Example—Place the instrument in the remote mode with the following statements:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="X":CALL IBWRT(M619%,CMD$) (return)
```

Now send GTL with the following statement:

```
CALL IBLOC(M619%) (return)
```

After return is pressed, the REMOTE indicator turns off, and the instrument goes into the local mode.

To permanently cancel LLO, send the following:

```
V%=0:CALL IBSRE (M619%,V%) (return)
```

3.9.5 DCL (Device Clear)

The DCL command may be used to clear the Model 619 and return it to its power-up default conditions. Note that the DCL command is not an addressed command, so all instruments equipped to implement DCL will do so simultaneously. When the Model 619 receives a DCL command, it will return to the default conditions listed in Table 3-12.

To send the DCL command, the controller must perform the following steps:

1. Set ATN true.
2. Place the DCL command byte on the data bus.

HP-85 Programming Example—Place the instrument in the amps mode and autorange with the front panel controls. Now enter the following statement into the HP-85 keyboard:

```
CLEAR 7 (END LINE)
```

Table 3-12. Default Conditions*

Mode	Default Value	Status
Function	F0	Volts
Range	R4	200V
Zero Check	C1	Enabled
Zero Correct	Z0	Disabled
Baseline Store	N0	Disabled
Baseline Suppress	U0	Disabled
Reading Rate	S3	4½ digits, 4 averaged conversions.
Trigger	T0	Continuous on talk.
Data Format	D0	ASCII
Data Storage Buffer	Q0	Disabled
Filter	P0	Disabled
Bus Response (SRQ)	M0	Disabled
Terminator	Y(LF)	CR LF
Channel**	A	Channel A selected.

*Status upon power-up or after DCL or SDC.
**Applies only to units equipped for dual-channel operation.

When the END LINE key is pressed, the instrument returns to the default conditions listed in Table 3-12.

Model 8573 Programming Example—Place the unit in the amps function, and autorange with the front panel controls. Now enter the following statement into the IBM computer:

```
CMD$=CHR$(&H14):CALL  IBCMD(BRD0%,CMD$)
                                (return)
```

When the return key is pressed, the instrument returns to the default conditions listed in Table 3-12.

3.9.6 SDC (Selective Device Clear)

The SDC command is an addressed command that performs essentially the same function as the DCL command. However, since each device must be individually addressed, the SDC command provides a method to clear only a single, selected instrument instead of clearing all instruments simultaneously, as is the case with DCL. When the Model 619 receives the SDC command, it will return to the power-up default conditions listed in Table 3-12.

To transmit the SDC command, the controller must perform the following steps:

1. Set ATN true.
2. Address the Model 619 to listen.
3. Send an appropriate secondary address.
4. Place the SDC command on the data bus.

With the SDC command, any secondary address in the range of 0-31 may be used.

HP-85 Programming Example—Using the front panel controls, place the instrument in the amps mode and autorange. Enter the following statements into the HP-85:

```
SEND 7; LISTEN 6 SCG 1 CMD 4 (END LINE)
```

After END LINE is pressed, the instrument returns to the power up default conditions listed in Table 3-12.

Model 8573 Programming Example—Place the instrument in the amps function and autorange with the front panel controls. Now enter the following statements into the IBM-PC:

```
CALL IBCLR(M619%) (return)
```

After the return key is pressed, the instrument returns to the default conditions listed in Table 3-12.

3.9.7 GET (Group Execute Trigger)

GET may be used to trigger the Model 619 to take readings if the instrument is placed in the appropriate trigger mode (more information on trigger modes may be found in paragraph 3.10.6).

To send GET, the controller must perform the following steps:

1. Set ATN true.
2. Place the GET command byte on the data bus.

HP-85 Programming Example—Type the following statements into the HP-85 keyboard to place the instrument in remote and enable the correct trigger mode for this demonstration:

```
REMOTE 7 (END LINE)
SEND 7; MTA LISTEN 6 SCG 1 (END LINE)
OUTPUT 7; "T3X" (END LINE)
```

Now send the GET command with the following statement:

```
TRIGGER 7 (END LINE)
```

When the END LINE key is pressed, the instrument will process a single reading, as indicated by the front panel TRIGGER indicator.

Model 8573 Programming Example—Type in the following statements to make sure the instrument is in the remote and correct trigger modes for purposes of this demonstration:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="T3X":CALL IBWRT(M619%,CMD$) (return)
```

Now send GET to the instrument with the following statement:

```
CALL IBTRG(M619%) (return)
```

When the return key is pressed, the instrument will process a single reading. The TRIGGER indicator will flash indicating a reading was processed.

3.9.8 SPE, SPD (Serial Polling)

The serial polling sequence is used to obtain the Model 619 status byte. The status byte contains important information about internal functions. Generally, the serial polling sequence is used by the controller to determine which of several instruments has requested service with the SRQ line. More details on the status byte may be found in paragraph 3.10.10.

The serial polling sequence is conducted as follows:

1. The controller sets ATN true.
2. The Model 619 is then addressed to talk.
3. The correct secondary address (6) for serial polling is sent.
4. The controller then places the SPE (Serial Poll Enable) command byte on the data bus. At this point, all active devices are in the serial poll mode and waiting to be addressed.
5. The controller sets ATN false.
6. The instrument then places its status byte in the data bus, at which point it is read by the controller.
7. The controller then sets ATN true and places the SPD (Serial Poll Disable) command byte on the data bus to end the serial polling sequence.

Once the instruments are in the serial poll mode, steps 3 through 5 above can be repeated by sending the correct talk address for each instrument. ATN must be true when addresses are transmitted and false when the status byte is read.

NOTE

The Model 619 status byte must be requested within 100msec of the SPE and Talk command, or it will return to default conditions.

HP-85 Programming Example—The HP-85 SPOLL statement automatically performs the sequence just described. To demonstrate serial polling, type in the following program.

PROGRAM	COMMENTS
10 REMOTE 7	Send remote enable.
20 SEND 7; UNT MLA TALK 6 SCG 6	Address to talk.
30 S=SPOLL (7)	Serial poll the 619.
40 DISP S	Display decimal value of status byte.
50 END	

In the above program, the instrument is first addressed to talk (line 20). Note that a secondary address of 6 is used to obtain the status byte. The serial polling sequence is then performed (line 30), and the decimal value of the status byte is then displayed on the computer CRT.

Model 8573 Programming Example—Add the following lines to the modified declaration file to demonstrate the basic serial polling sequence.

PROGRAM	COMMENTS
20 V%=1:CALL IBSRE (BRD0%,V%)	Send remote enable.
30 V%=&H66:CALL IBSAD (M619%,V%)	Change to serial poll secondary address.
40 CALL IBRSP(M619%,SB%)	Serial poll the 619.
50 PRINT SB%	Display decimal value of status byte.
60 V%=&H61:CALL IBSAD (M619%,V%)	Return secondary address parameter to channel A.
70 V%=0:CALL IBONL (M619%,V%)	Close instrument file.
80 CALL IBONL(BRD0%,V%)	Close board file.

In this program, the Model 8573 software is first configured for the proper secondary address to serial poll the instrument (line 30). The instrument is then serial polled and the status byte is displayed (lines 40 and 50). The secondary address parameter is then returned to the value necessary for channel A access (line 50).

3.10 DEVICE-DEPENDENT COMMAND PROGRAMMING

IEEE-488 device-dependent commands are used with the Model 619 to control various operating modes such as function, range, trigger mode and data format. Each command is made up of a single ASCII letter followed by a number representing an option of that command. For example, a command to control the measuring function (Volts, Ohms, Amps) is programmed by sending an ASCII "F" followed by a number representing the function option. The IEEE-488 bus actually treats these commands as data in that ATN is false when the commands are transmitted.

A number of commands may be grouped together in one string. A command string is usually terminated with an ASCII "X" character, which tells the instrument to execute the command string. Commands sent without the execute character will not be executed at that time, but they will be retained within an internal command buffer for execution at the time the X character is received. If any errors occur, the instrument will display appropriate front panel error messages and generate an SRQ if programmed to do so.

NOTE

Once a command string is sent, the instrument must receive an appropriate trigger to update the reading.

String examples include:

F0X Single command string.
F0D0R0X Multiple command string.
T4 X Spaces are ignored

Typical invalid command strings include:

H1X Invalid command, as H is not one of the instrument commands.
F9X Invalid command option because 9 is not an option of the F command.

If an illegal command (IDDC), illegal command option (IDDCO), is sent, or if a command string is sent with REN false, the string will be ignored. The instrument will generate a front panel error message, as summarized in Table 3-13.

NOTE

Once a front panel error message is displayed, the instrument must be triggered to restore the display to normal operation. Either press the RATIO A/B or DIFFERENCE A-B buttons, or trigger the unit (paragraph 3.10.6).

Device-dependent commands that control the Model 619 are listed in Table 3-14. These commands are covered in detail in the following paragraphs. The associated programming examples show how to send the commands with both the HP-85 and the IBM-PC/8573.

NOTE

Programming examples assume that the Model 619 is at its factory default value of 6, and with a secondary address of 1 (channel A).

In order to send a device-dependent command, the controller must perform the following steps:

1. Set ATN true.
2. Address the Model 619 to listen.
3. Send the appropriate secondary address.
4. Set ATN false.
5. Send the command string over the bus one byte at a time.

All device-dependent commands except T (trigger mode), D (data format), and buffer are channel dependent, meaning that each channel can be separately programmed. When sending device-dependent commands, be sure to use the correct secondary address for the channel in question. To command channel A, send a secondary address of 1 (&H61); to access channel B, use a secondary address of 2 (&H62). The same requirements also hold true when accessing instrument data.

General HP-85 Programming Example—Device-dependent commands may be sent from the HP-85 with the following statments:

```
SEND 7; UNL MTA LISTEN 6 SCG1
OUTPUT 7; A$
```

A$ in this case contains the ASCII characters representing the command string. With the secondary address given in this example, channel A will be accessed. To access channel B, the SCG parameter in the above statement would be changed to 2.

General Model 8573 Programming Example—Use the following general syntax to send device-dependent commands from the IBM-PC:

```
CALL IBWRT (M619%,CMD$)
```

Again, CMD$ contains the command letters to program the instrument. Remember that the modified declaration file must be run before using any programming examples. Use the IBSAD statement to set the secondary address to access the desired channel (&H61 for channel A, or &H62 for channel B).

Table 3-13. Front Panel Error Messages Associated with IEEE-488 Operation

Message	Description
no rn	Instrument not in remote when programmed (REN false).
IddC	Illegal Device-Dependent Command (Example: H1X).
IddCO	Illegal Device-Dependent Command Option (Example: T9X).
ISbS	Invalid string with baseline store (Function change command in same string as baseline store command).

3.10.1 Execute (X)

The execute command is implemented by sending an ASCII "X" over the bus. Its purpose is to direct the Model 619 to execute other device-dependent commands such as F (function) or R (range). Usually, the execute character is the last byte in the command string (a number of commands may be grouped together into one string); however, there may be certain circumstances where it is desirable to send a command string at one time, and then send the execute character later on. Command strings sent without the execute character will be stored within an internal command buffer for later execution. When the X character is finally transmitted, the stored commands will be executed, assuming that all commands in the previous string were valid.

HP-85 Programming Example—Enter the following statements into the HP-85 keyboard:

```
REMOTE 7 (END LINE)
SEND 7, UNL MTA LISTEN 6 SCG 1 (END LINE)
OUTPUT 7;"X" (END LINE)
```

When the END LINE key is pressed the third time, the X character will be transmitted to the instrument. No mode changes will occur with this example because no other commands were sent. Note that the instrument remains in the listener active state after the command is transmitted.

Model 8573 Programming Example—Enter the following statements into the IBM computer:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="X":CALL IBWRT(M619%,CMD$) (return)
```

When the return key is pressed the second time, the X character is transmitted to the instrument, although no mode changes occur because no other commands are transmitted. Note that the instrument remains in the listener idle state after the command is transmitted because IBWRT automatically sends UNT (Untalk) and UNL (Unlisten) at the end of the transmission sequence.

Table 3-14. Device-Dependent Command Summary

Mode	Command	Description	Paragraph
Execute	X	Execute device-dependent commands	3.10.1
Function	F0* F1 F2	Volts Amps Ohms	3.10.2
Range		Volts / Amps / Ohms	3.10.3
	R0	Auto / Auto / Auto	
	R1	200mV / 2nA / 2 kΩ	
	R2	2 V / 20 nA / 20 kΩ	
	R3	20 V / 200 nA / 200 kΩ	
	R4*	200 V / 2 μA / 2MΩ	
	R5	200 V / 20μA / 20MΩ	
	R6	200 V / 200μA / 200MΩ	
	R7	200 V / 2mA / 2GΩ	
	R8	200 V / 20mA / 20GΩ	
	R9	200 V / 2 A / 200GΩ	
	R:	200 V / Ext Feedback / 2TΩ	
Data Format	D0* D1	ASCII Binary	3.10.4
Reading Rates		Conversions Averaged / Integration Period (ms) / Usable Resolution	3.10.5
	S0	1 / 4.1 / 3½ Digits	
	S1	1 / 16.66(20,50Hz) / 4½	
	S2	2 / 16.66(20,50Hz) / 4½	
	S3*	4 / 16.66(20,50Hz) / 4½	
	S4	1 / 100 / 5½	
	S5	2 / 100 / 5½	
	S6	4 / 100 / 5½	
	S7	8 / 100 / 5½	
	S8	16 / 100 / 5½	
	S9	32 / 100 / 5½	
Trigger	T0* T1 T2 T3 T4 T5	Continuous on Talk One-shot on Talk Continuous on GET One-shot on GET Continuous on X One-shot on X	3.10.6
Zero Check	C0 C1*	Disabled Enabled	3.10.7
Zero Correct	Z0* Z1	No Correction Make correction	3.10.7
Baseline Store	N0* N1	No storage Store Baseline	3.10.8

Table 3-14. Device-Dependent Command Summary (Cont.)

Mode	Command	Description	Paragraph
Baseline Suppression	U0* U1	Disabled Enabled	3.10.8
Data Storage Buffer	Q0* Q1 Q2 Q3 Q4 Q5	Disabled 10 Readings 20 Readings 30 Readings 40 Readings 50 Readings	3.10.9
SRQ	M0* M1	SRQ Disabled SRQ Enabled	3.10.10
Filter	P0* P1	Filter Off Filter On	3.10.11
Terminator	Y <DEL> Y <CR> Y <LF> * Y(ASCII)	No Terminator <LF><CR> <CR> <LF> Any ASCII except F, R, M, T, D, Q, Y, S, P, Z, N, U, X	3.11.12

*Power on/DCL/SDC.

3.10.2 Function (F)

The function command allows you to select the type of measurements made by the Model 619. The parameter options associated with the function command set the instrument to measure voltage, current or resistance. Each channel may be programmed separately by using the correct secondary address. The function may be programmed by sending one of the following commands:

F0=Volts
F1=Amps
F2=Ohms

Upon power-up, or after the instrument receives a DCL or SDC command, the F0 (volts) mode will be enabled.

HP-85 Programming Example—Place the instrument in the current function with the front panel AMPS button and enter the following statements into the HP-85 keyboard:

REMOTE 7 (END LINE)
SEND 7; UNL MTA LISTEN 6 SCG 1 (END LINE)
OUTPUT 7; "F0X" (END LINE)

When END LINE is pressed the second time, the instrument changes to the volts mode, as indicated by the associated LED.

Model 8573 Programming Example—Place the instrument into the current mode with the front panel AMPS button. Now type the following statements into the computer keyboard:

V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="F0X":CALL IBWRT(M619%,CMD$) (return)

When the return key is pressed the second time, the instrument changes to the volts function.

3.10.3 Range (R)

The range command gives the user control over the sensitivity of the instrument. This command, and its options, perform essentially the same functions as the front panel AUTO/MANUAL and UPRANGE and DOWNRANGE buttons. Range command parameters and the respective ranges for each measuring function are summarized in Table 3-15. Each channel may be separately programmed by using the appropriate secondary address.

Upon power up, or after receiving a DCL or SDC command, the instrument will be in the R4 (200V) range.

Table 3-15. Range Command Summary

Command	Volts	Amps	Ohms
R0	Auto	Auto	Auto
R1	200mV	2 nA	2 kΩ
R2	2 V	20 nA	20 kΩ
R3	20 V	200 nA	200 kΩ
R4	200 V	2 μA	2MΩ
R5	200 V*	20 μA	20MΩ
R6	200 V*	200 μA	200MΩ
R7	200 V*	2mA	2GΩ*
R8	200 V*	20mA	20GΩ*
R9	200 V*	2 A*	200GΩ*
R:	200 V*	EXT FEEDBACK**	2TΩ*
Pwr ON/DCL/SDC Default R4			

*Will not autorange into these ranges.
**EXT FEEDBACK is considered to be an Amps range and not an individual function.

HP-85 Programming Example—Make sure the instrument is in the manual mode and then enter the following statements into the HP-85:

REMOTE 7 (END LINE)
SEND 7; UNL MTA LISTEN 6 SCG 1 (END LINE)
OUTPUT 7;"R0X" (END LINE)

When the END LINE key is pressed the second time, the instrument enters the autorange mode on channel A.

Model 8573 Pogramming Example—Make sure the instrument is in the manual mode. Now enter the following statements into the IBM-PC keyboard:

V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="R0X":CALL IBWRT(M619%,CMD$) (return)

When the return key is pressed the second time, the instrument enters the autorange mode.

Optimum Bus Range Selection—In most cases, it is best to use the lowest range possible without overranging the instrument, as doing so will optimize accuracy. Since the Model 619 is equipped with a convenient autoranging mode, it may be expedient to use the R0 mode in many situations. Keep in mind, however, that numerous range changes could slow down measurement cycles considerably. If speed is a consideration, it will be best to program specific manual ranges from the controller. Thus, if a wide range of test signals are to be applied in an automated system, a range changing algorithm in the controlling program may provide a better solution that the instrument's own built-in autoranging mode.

Because of the way the Model 619 measures current, alternate amps ranges are subject to slightly more noise than the others. The noisier ranges include the 2nA, 200nA, 20μA and 2mA ranges, while the quieter ranges are 20nA, 2μA, 200μA and 20mA ranges. If noise is a consideration, the unwanted ranges can be avoided by using an alternate range algorithm in the controller. The two examples below will demonstrate the basic procedure for providing this capability.

HP-85 Programming Example—Enter and run the program below in order to demonstrate alternate ranging.

```
PROGRAM                                  COMMENTS
10 REMOTE 7                              Send remote enable.
20 CLEAR                                 Clear CRT.
30 CLEAR 7                               Send DCL.
40 C$="F1T1R1X"@GOSUB 210                Program amps, one-
                                         shot, 2nA range.
50 C$="Z1X"@GOSUB 210                    Zero correct the 619.
60 GOSUB 240                             Trigger a reading.
70 R=2                                   Set range parameter
                                         for 20nA range.
80 C$="C0X"@ GOSUB 210                   Disable zero check.
90 C$="R"&VAL$(R)&"X"                    Define range com-
                                         mand string.
100 GOSUB 210                            Program range.
110 GOSUB 240                            Get a reading string.
120 IF A$[1,1]#O THEN 160                Check for reading
                                          overflow; if none,
                                          go to 160.
130 R = R+2                              Increment range
                                         parameter to next
                                         higher alternate
                                         range.
140 IF R>8 THEN DISP "CUR-               Check for current
    RENT ABOVE 20mA"@                    limits.
    GOTO 30
150 GOTO 90                              Go back and pro-
                                         gram next alternate
                                         range.
160 DISP A$                              Display the reading.
170 C$="C1X"@ GOSUB 210                  Turn on zero check.
180 DISP"APPLY CURRENT,                  Wait for next cur-
    PRESS 'CONT' "                       rent input.
```

```
190 PAUSE
200 GOTO 70                          Go back and
                                     measure again.
210 SEND 7; UNL MTA LISTEN 6         Subroutine to trans-
    SCG 1                            mit command string.
220 OUTPUT 7; C$
230 RETURN
240 SEND 7; UNT MLA TALK 6           Subroutine to get
    SCG 1                            reading string.
250 ENTER 7; A$
260 RETURN
270 END
```

In the above program, the instrument is programmed for the 2nA range and placed in the one-shot mode (line 40). The instrument is then zero corrected (line 50). The BASIC variable R holds the range parameter value. Initially, it is defined for the R2, or 20nA range, which is the lowest of the quieter ranges (line 70). Next the unit is taken out of zero check (line 80), and the instrument is then programmed to the required range (lines 90 and 100). A reading is then obtained from the instrument (line 110), and the reading string is then checked to see of the reading is overflowed.

If the reading is overflowed, the range parameter is then incremented to the next higher alternate range (line 130), and then checked for limits (line 140). If the reading is not an overflow reading, it is displayed (line 160), and the cycle repeats.

Model 8573 Programming Example—Add the lines below to the modified declaration file (paragraph 3.8.2) to demonstrate alternate range selection.

PROGRAM	COMMENTS
20 V%=1:CALL IBSRE (BRD0%,V%)	Send remote enable.
30 CLS	Clear screen.
40 CALL IBCLR(M619%)	Send SDC to 619.
50 CMD$="F1T1R1X":CALL IBWRT(M619%,CMD$)	Program 2nA range, one-shot on talk modes.
60 CMD$="Z1X":CALL IBWRT (M619%,CMD$)	Zero correct the 619.
70 RD$=SPACE$(20)	Define reading input. buffer.
80 CALL IBRD(M619%,RD$)	Trigger a reading.
90 R=2	Define range parameter for 20nA range.
100 CMD$="C0X":CALL IBWRT (M619%,CMD$)	Disable zero check.
110 CMD$="R"+STR$(R)+"X"	Define range command string.
120 CALL IBWRT(M619%,CMD$)	Program range.
130 RD$=SPACE$(20)	Define reading input buffer.
140 CALL IBRD(M619%,RD$)	Get a reading.
150 IF LEFT$(RD$,1)<>"O" THEN 190	Check for overflow.
160 R=R+2	Increment range parameter to alternate range.
170 IF R>8 THEN PRINT "CURRENT ABOVE 20mA": GOTO 40	Check for upper current limit.
180 GOTO 110	Program next alternate reading.
190 PRINT RD$	Display the reading.
200 PRINT"APPLY CURRENT, PRESS KEY ('Q' TO QUIT)"	Wait for next current input.
210 B$=INKEY$:IF B$="" THEN 210	
220 IF B$<>"Q" THEN 90	Go back and measure again.
230 V%=0:CALL IBONL (M619%,V%)	Close instrument file.
240 CALL IBONL(BRD0%,V%)	Close board file.

The instrument is first programmed for the 2nA range and then placed in the one-shot on talk trigger mode (line 50). Next, the instrument is zero corrected to ensure best accuracy (line 60). The range parameter, R, is then assigned a value of 2, which is the value necessary for the 20nA range (line 90). Zero check is next disabled (line 100), and the range is then programmed (lines 110 and 120). A reading is obtained from the instrument (line 140), and the result is checked to see if an overflow has occurred (line 150).

If the reading is overflowed, the range parameter is incremented to the next alternate range (line 160), and the parameter is checked for limits (line 170). If the limits have not been exceeded, the program repeats for the next higher range.

If the reading is not overflowed, the reading string is then displayed, and the process repeats.

3.10.4 Data Format (D)

The D command allows the selection of ASCII or binary data formats when requesting data from the Model 619. Note that this command affects both channels simultaneously. The two options of the D command include:

D0=ASCII data
D1=Binary data

Upon power up, or after a DCL, the instrument will be in the D0 (ASCII) mode.

ASCII Data Format—The D0 mode will transmit a string of ASCII characters, as shown in Table 3-16. The first four characters will show the type of reading (normal or overflow), and the measured function (volts, amps, or ohms). The reading itself consists of a 5½ digit signed mantissa and a two-digit signed exponent. The terminator sequence will depend on the programmed terminator value (paragraph 3.10.13); a default CR LF sequence is normally used. Thus, the complete ASCII string will be made up of 16 to 18 characters depending on the programmed number of terminators.

Table 3-16. ASCII Data Formats (D0)

Function	Data**
Volts	*NDCV ±1.23456E±09 (Terminators)
Amps	NDCA ±1.23456E±09 (Terminators)
Ohms	NOHM ±1.23456E±09 (Terminators)

*N = Normal Reading
0 = Overflow Reading
**Default terminators: CR(13) LF(10)

Binary Data Format—When the instrument is in the D1 mode, it will transmit its data with the binary format shown in Figure 3-9. The transmission sequence consists of five bytes: four bytes of data and a dummy byte. During the dummy byte transmission, EOI will be asserted to mark the end of the transmission. Note that the usual terminators are not sent in the D1 mode. Thus, many controller input sequences will have to be modified to terminate on EOI rather than on the CR LF sequence used with the D0 (ASCII) mode. When the instrument is in the D1 mode, the front panel display and all annunciators except those associated with the IEEE-488 bus will be off.

The various bits are defined as follows:

1. First byte:
   A. The most significant bit is the sign bit. This bit will be set to 1 if the reading is negative, and 0 if the reading is positive.
   B. The second bit determines whether the reading is a normal or overflow reading. If this bit is set to 1, the reading is overflowed. If the bit is 0, a normal reading has been transmitted.
   C. The remaining six bits of byte one are the most significant bits of the 22-bit mantissa.
2. Second and third bytes: 16 bit binary data.
3. Fourth byte: Exponent of the data in 2s complement form.
4. Fifth byte: During transmission of this dummy byte, EOI will be asserted to mark the end of the transmission sequence.

The mantissa can be converted into a decimal equivalent simply by adding up the decimal values for the various bit positions that are set to 1. Table 3-17 gives the decimal equivalent values for the various bit values.

The exponent, which is the fourth byte, can be converted into decimal in a similar manner. However, since the exponent is in 2s complement form, the following rules apply:

1. If the most significant bit (B7) is 0, exponent is positive, and the remaining bits may be converted by adding up the decimal equivalents for those bit positions that are set to 1. Table 3-18 gives the decimal weighting for bits B6-B0.
2. If the most significant bit is 1, the exponent is negative. To convert bits 0-6 to straight binary, add binary 1 to the exponent value and discard B7 and any carry. The remaining bits can be converted to decimal by using the values listed in Table 3-18.

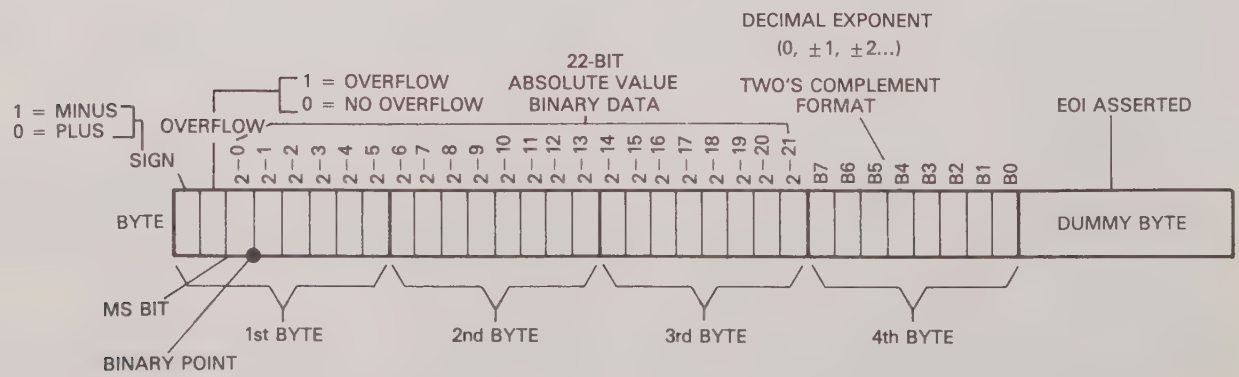


Figure 3-9. Binary Data Format (D1 Mode)

Table 3-17. Equivalent Decimal Values for Binary Mantissa

Binary Value	Decimal Equivalent
2-0	1
2-1	.5
2-2	.25
2-3	.125
2-4	.0625
2-5	.03125
2-6	.015625
2-7	.0078125
2-8	.00390625
2-9	.001953125
2-10	.0009765625
2-11	.000244140625
2-13	1.220703125E-4
2-14	6.103515625E-5
2-15	3.0517578125E-5
2-16	1.5258790625E-5
2-17	7.62939453125E-6
2-18	3.81469726563E-6
2-19	1.90734863282E-6
2-20	9.5367431641E-7
2-21	4.76837158205E-7

Table 3-18. Equivalent Decimal Values for Binary Exponent

Exponent Bit	Decimal Equivalent
B0	1
B1	2
B2	4
B3	8
B4	16
B5	32
B6	64

Obtaining Data—Whether the ASCII or binary data format is used, data can be obtained by the controller by using the following basic input sequence.

1. The controller places the ATN line true.
2. The instrument is addressed to talk by placing its talk address on the bus.
3. The correct secondary address for the channel to be accessed is placed on the bus [1($61)=channel A; 2($62)=channel B].
4. The controller sets ATN false.
5. The instrument than places its data on the bus one byte at a time to be read by the controller.

HP-85 Programming Example—To demonstrate both ASCII and binary data formats, enter and run the program below.

```
PROGRAM                          COMMENTS
10 REMOTE 7                      Send remote enable.
20 SEND 7; UNL MTA LISTEN 6 SCG 1   Address instrument to listen.
30 OUTPUT 7;"D0X"                Program for ASCII format.
40 SEND 7; UNT MLA TALK 6 SCG 1  Address instrument to talk.
50 ENTER 7; A$                   Input ASCII data string.
60 DISP A$                       Display ASCII data string.
70 SEND 7; UNL MTA LISTEN 6 SCG 1   Address instrument to listen.
80 OUTPUT 7; "D1X"               Program instrument for binary format.
90 SEND 7; UNT MLA TALK 6 SCG 1  Address instrument to talk.
100 ENTER 7 USING "%,%K"; B$     Input binary data, terminate on EOI.
110 FOR I=1 TO 4                 Loop four times.
120 A$=B$[I,I]                   Get individual byte.
130 A=NUM(A$)                    Convert to ASCII value.
140 GOSUB 170                    Display the bits.
150 NEXT I                       Do next data byte.
160 END
170 FOR J=7 TO 0 STEP -1         Subroutine to display bits.
180 B=BIT(A,J)                   Get bit value.
190 C$=VAL$(B)                   Convert it to string.
200 DISP C$;                     Display the bit value.
210 NEXT J                       Do next bit in current byte.
220 RETURN                       Return from subroutine.
```

In the above program, the instrument is programmed for the ASCII format (lines 20 and 30), the ASCII data string is then obtained and displayed (lines 40-60), the data format is changed to binary (lines 70 and 80), and binary data is then obtained from the instrument (lines 90 and 100). The ENTER USING statement is necessary in this instance so that the computer terminates on EOI because the instrument transmits no standard terminators while in the binary mode. The subroutine beginning at line 170 is used to display the individual bits of each of the four bytes in the binary data.

Model 8573 Programming Example—Add the following lines to the modified declaration file (paragraph 3.8.2) to demonstrate both ASCII and binary data formats.

```
PROGRAM                              COMMENTS
20 V%=1:CALL IBSRE                   Send remote enable.
   (BRD0%,V%)
30 CMD$="D0X":CALL IBWRT             Program for ASCII
   (M619%,CMD$)                      format.
40 RD$=SPACE$(25)                    Define reading input
                                     buffer.
50 CALL IBRD(M619%,RD$)              Get ASCII data string
                                     from instrument.
60 PRINT RD$                         Display ASCII data
                                     string.
70 CMD$="D1X":CALL IBWRT             Program binary data
   (M619%,CMD$)                      format.
80 RD$=SPACE$(6)                     Define reading input
                                     buffer.
90 CALL IBRD(M619%,RD$)              Get binary data string.
100 FOR I=1 TO 4                     Loop four times.
110 A=ASC(MID$(RD$,I,1))             Convert byte to
                                     numeric value.
120 GOSUB 150                        Convert to bit display.
130 NEXT I                           Do next byte.
140 GOTO 210
150 MASK%=128                        Set mask for MSB.
160 FOR J=1 TO 8                     Loop for all eight bits.
170 IF (MASK% AND A)                 Mask off the bits.
    THEN PRINT"1"; ELSE
    PRINT"0";
180 MASK%=MASK%/2                    Set mask for next bit
                                     position.
190 NEXT J                           Go back and do next
                                     bit.
200 RETURN
210 V%=0:CALL IBONL                  Close instrument file.
    (M619%,V%)
220 CALL IBONL(BRD0%,V%)             Close board file.
```

In the above program, the instrument is first programmed for the ASCII data format (line 30), and the ASCII data string is then obtained and displayed (lines 40-60). The unit is programmed for the binary data format (line 70), after which the binary data bytes are then obtained (lines 80 and 90). No special programming is necessary with the Model 8573 because the interface automatically terminates on EOI.

The subroutine beginning at line 150 is used to mask off the bit values and display them one by one.

3.10.5 Reading Rate (S)

Through use of the rate command, one of 10 selected reading rates may be used, as summarized in Table 3-19. The rate command affects the number of conversions averaged, the integration period, and the useable resolution of the instrument. Note that data string returned by the instrument is always 5½ digits; however, the useable resolution will be only 3½ digits in S0, or 4½ digits in the S1 through S3 modes.

The S3 and S5 modes correspond to those rates in effect when 4½ or 5½ digit resolution is selected from the front panel. In S0, the display will be blanked and all annunciators except for those associated with IEEE-488. In addition, a separate rate may be progammed for each channel by using the correct secondary address.

Upon power up, after a DCL or SDC, the S3 mode will be enabled.

HP-85 Programming Example—Enter the following statements to program the instrument to the S0 rate mode:

```
REMOTE 7 (END LINE)
SEND 7; UNL MTA LISTEN 6 SCG 1 (END LINE)
OUTPUT 7; "S0X" (END LINE)
```

When the END LINE key is pressed the third time, the instrument is programmed for the S0 mode on channel A.

Table 3-19. Reading Rate Modes

Mode	Continuous rdg/sec (ASCII)	Conversions Averaged	Integration Period (ms)	Usable Resolution†	Trigger to First** Byte Delay	
					ASCII D0	Binary D1
S0	40	1	4.1	3½	31.5	18
S1	21.2	1	16.66*	4½	34.5	30.5
S2	10.7	2	16.66*	4½	80	75
S3***	6.2	4	16.66*	4½	168	164
S4	4.83	1	100	5½	119	112
S5***	2.41	2	100	5½	328	323
S6	1.20	4	100	5½	741	736
S7	0.60	8	100	5½	1680	1680
S8	0.30	16	100	5½	3300	3300
S9	0.15	32	100	5½	6700	6700

†5½ digits always transmitted over bus.
*20msec at 50Hz.
**In msec ±250μsec.
***Available in front panel operation via RESOLUTION pushbutton.

NOTE: Default rate (power-up, DCL or SDC) is S3.

Model 8573 Programming Example—To program the instrument for the S0 rate mode, enter the following statements into the IBM computer.

```
V%=1:CALL IBSRE(M619%,V%) (return)
CMD$="S0X":CALL IBWRT(M619%,CMD$) (return)
```

When the second statement above is executed the instrument changes to the S0 mode.

Rate Selection Considerations—The optimum rate for a given application will depend on the required speed of the measurement, the necessary resolution, and the amount of noise in the reading that is tolerable. Generally, there is a trade-off among these three chracteristics. For example, to take more readings per second, the integration period must be shortened. Doing so decreases the resolution of the A/D converter. Another factor that can decrease the reading rate is the number of conversions that are averaged. Such averaging is incorporated into the conversion cycle to minimize noise in the final reading. Thus, if a faster rate is required, it will be necessary to minimize the amount of averaging taking place, thus increasing the amount of noise in the final reading.

In looking over Table 3-19, we can see that the various parameters associated with the 10 available rate modes follow the preceding discussion. The S0 mode, for example is the fastest rate because it has the shortest integration period (4.1msec) and converts only one reading. At the other extreme, the S9 rate is the slowest because it has a longer integration period (100msec and averages 32 readings. In between these two extremes, the remaining rate modes offer various degrees of compromise among speed, resolution, and noise.

At lower signal levels, it is better to select a rate mode that will result in more averaged readings to minimize noise. However, keep in mind that doing so will slow down the reading rate. Thus, it may be necessary to compromise on a rate that results in the necessary reading rate and resolution, but at the same time yields a tolerable noise level.

3.10.6 Trigger (T)

Triggering provides a stimulus to begin a reading within the instrument. Triggering may be done in two basic ways: in a continuous mode, a trigger is used to re-start a continuous series of readings; in a one-shot trigger mode, a single reading will be processed each time the appropriate trigger is given.

The Model 619 has six trigger modes as follows:

T0 Continuous Mode, Triggered by Talk

T1 One-shot Mode, Triggered by Talk
T2 Continuous Mode, Triggered by GET
T3 One-Shot Mode, Triggered by GET
T4 Continuous Mode, Triggered by X
T5 One-shot Mode, Triggered by X

The trigger modes are paired according to the type of trigger stimulus. In the T0 and T1 modes, triggering is performed by addressing the Model 619 to talk. An appropriate secondary address must also accompany the talk command. In T2 or T3, the multiline GET command is used to trigger the instrument. In T4 or T5, the execute (X) character triggers the instrument.

NOTES:

1. The front panel RATIO A/B or DIFFERENCE A-B buttons may be used to trigger the instrument in a one-shot mode as long as LLO is not in effect.
2. After sending a device-dependent command, an appropriate trigger stimulus must be sent to the instrument to update the display. The trigger stimulus necessary will depend on the selected trigger mode.
3. The selected trigger mode affects both channels. Thus, separate trigger modes for the two channels cannot be selected.

HP-85 Programming Example—Enter the following statements to place the unit in the one-shot, GET trigger mode:

```
REMOTE 7 (END LINE)
SEND 7; UNL MTA LISTEN 6 SCG 1 (END LINE)
OUTPUT 7;"T3X" (END LINE)
```

When the third statement above is executed, the instrument will enter the T3 mode.

The instrument can now be triggered by sending GET as follows:

```
TRIGGER 7 (END LINE)
```

Note that the TRIGGER and UPDATE indicators flash once when the above statement is executed.

Model 8573 Programming Example—Enter the following statements to place the unit in the T3 mode:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="T3X":CALL IBWRT(M619%,CMD$) (return)
```

To trigger a reading, send the GET command with the following statement:

```
CALL IBTRG(M619%) (return)
```

When the above statement is executed, the instrument will be triggered, as indicated by the single flash of the TRIGGER and UPDATE indicators.

3.10.7 Zero Check and Zero Correct (C and Z)

The zero check and zero correct commands work together to cancel any internal offsets that might upset accuracy. If the instrument is zero corrected with zero check enabled, it will perform the zero correction process and internally store the value to be used with subsequent readings. If zero check is disabled when attempting to zero correct, the instrument will display the "Corr Il" message, and it may be programmed to generate an SRQ under these conditions (paragraph 3.10.10).

Zero correct and zero check commands include:

C0=Zero check off
C1=Zero check on
Z0=Zero correct off
Z1=Zero correct on

Internally, the Model 619 has six zero correct registers, one each for the three measuring functions (volts, amps, ohms) with each channel. The zero check mode (either on or off) may also be independently selected for each channel.

Upon power up, or after receiving a DCL or SDC command, the instrument will be in the C1 zero check on) and Z0 (correction disabled) modes. Once Z1 is sent to zero correct the instrument, it is not necessary to send Z0 to disable zero correct, as the instrument will do this automatically once the zero correction process is complete.

Use the following procedure to zero correct the instrument:

1. Select the lowest range of the function to be zero corrected on the channel in question. For example, to zero correct the volts function, send the following command string: F0R1X.
2. Enable zero check by sending C1X.
3. Zero correct the instrument by sending Z1X.
4. Repeat the above procedure, as required for the other channel and functions.
5. Disable zero check and select the desired range to make a measurement.

NOTES:

1. Do not zero correct the instrument while in the autorange mode.
2. Zero check is not available in the 2A range. The "no 2A C" error message will be displayed, and the instrument may be programmed to generate an SRQ under these conditions, as described in paragraph 3.10.10.
3. The instrument must receive an appropriate trigger after receiving the zero correct or zero check command before it will complete the process. For example, if the unit is in the T1 trigger mode (one-shot on talk) it will be necessary to address the instrument to talk after sending Z1X. This talk command must be immediately followed by the correct secondary address for the selected channel. Paragraph 3.10.6 discusses triggering in more detail.

HP-85 Programming Example—The program below demonstrates the basic procedure for zero correcting the instrument.

```
PROGRAM                                  COMMENTS

 10 CLEAR                                Clear CRT.
 20 CLEAR 7                              Send DCL.
 30 REMOTE 7                             Send remote enable.
 40 C$="F1R1T1X"@GOSUB 130               Select amps, lowest
                                         range, one-shot.
 50 C$="C1XZ1X"@GOSUB 130                Zero check, then zero
                                         correct.
 60 GOSUB 160                            Get corrected reading.
 70 DISP A$                              Display the reading.
 80 C$="C0R5X"@GOSUB 130                 Zero check off, 20μA
                                         range.
 90 GOSUB 160                            Get a reading.
100 DISP A$                              Display reading.
110 C$="C1X"@GOSUB 130                   Turn zero check on.
120 END
130 END 7; UNL MTA LISTEN 6              Subroutine to transmit
    SCG 1                                command.
140 OUTPUT 7; C$
150 RETURN
160 SEND 7; UNT MLA TALK 6               Subroutine to get
    SCG 1                                reading from instru-
                                         ment.
170 ENTER 7; A$
180 RETURN
```

In the above program, the instrument is placed on the lowest range of the amps function (line 40) and then zero corrected (line 50). A reading is then obtained while zero check is enabled (line 90). The instrument is then placed on the 20A range, and zero check is disabled to take a reading.

Model 8573 Programming Example—Add the lines below to the modified declaration file (paragraph 3.8.2) to demonstrate the basic procedure for zero correcting the instrument.

```
PROGRAM                                  COMMENTS

 20 CLS                                  Clear screen.
 30 V%=1:CALL IBSRE                      Send remote enable.
    (BRD0%,V%)
 40 V%=&H102:CALL IBPOKE                 Disable timeouts.
    (BRD0%,V%)
 50 CALL IBCLR(M619%)                    Send SDC to 619.
 60 CMD$="F1R1T1X":CALL                  Select amps, lowest
    IBWRT(M619%,CMD$)                    range, one-shot
                                         mode.
 70 CMD$="C1XZ1X":CALL                   Zero correct 619.
    IBWRT(M619%,CMD$)
 80 RD$=SPACE$(20)                       Define reading input
                                         buffer.
 90 CALL IBRD(M619%,RD$)                 Get reading from 619.
100 PRINT RD$                            Print the reading.
110 CMD$="R5C0X":CALL                    Zero check off, 20μA
    IBWRT(M619%,CMD$)                    range.
120 RD$=SPACE(20)                        Define reading input
                                         buffer.
130 CALL IBRD(M619%,RD$)                 Get reading from 619.
140 PRINT RD$                            Print reading.
150 CMD$="C1X":CALL                      Turn zero check on.
    IBWRT(M619%,CMD$)
160 V%=0:CALL IBONL                      Close instrument file.
    (M619%,V%)
170 CALL IBONL                           Close instrument file.
```

In the preceding program, the instrument is placed on the 20A range (line 60) and then zero corrected (line 70). A reading is then requested and displayed (lines 90 and 100), and zero check is then disabled (line 110) and a second reading is then requested and displayed (lines 130 and 140).

3.10.8 Baseline Store (N) and Baseline Suppression (U)

The baseline store and baseline suppression commands work together to allow a stored baseline value to be subtracted from subsequent readings. By using the baseline store (N) command, six different baseline values can be stored: channel A volts, channel A amps, channel A ohms, channel B volts, channel B amps, and channel B ohms. Once the baseline values are stored, the baseline suppression command can be used to subtract these values from subsequent readings. For example, if 100mV is stored as a baseline, that value will be subtracted from subsequent readings.

Baseline store and baseline suppression commands include:

N0=Baseline storage register not updated.
N1=Store baseline for selected channel and function, and return to N0.
U0=Baseline suppression disabled (register contents not subtracted from signal).
U1=Baseline suppression enabled (register contents subtracted from reading).

Upon power up, or after a DCL or SDC, the instrument will be in the N0 and U0 modes (both disabled).

Storing Baseline Values—Use the following basic sequence to store baseline values.

1. Select the channel, and a functions and range that is consistent with the anticipated measurement.
2. Connect the signal to be used as a baseline value to the instrument input.
3. Disable zero check.
4. Store the baseline by sending N1X. The instrument will then store the value with the next triggered conversion. For example, if in T0 (default) address the unit to talk (include correct secondary address).
5. Repeat the above procedure for the remaining measuring functions and the other channel, as required.

Using Baseline Suppression—Once baseline values are stored in internal baseline registers, they may be subtracted from subsequent readings as follows:

1. Connect the signal to be measured to the instrument input.
2. Disable zero check if enabled.
3. Enable baseline suppression by sending U1X.
4. Subsequent readings displayed and sent over the bus will be the difference between the actual signal level and the stored baseline.

WARNING

The voltage present on the input terminals may be larger than the displayed value. For example, if a 150V baseline is stored, an applied voltage of 175V will result in a displayed value of only 25V. The BASELINE SUPPRESSION indicator will flash when the instrument is on the 200V range to indicate a possible safety hazard.

NOTES:

1. The instrument must receive an appropriate trigger to complete the baseline store and baseline suppress commands. For example, if the instrument is in the T1 (one-shot on talk) trigger mode, it must be addressed to talk to trigger the instrument. This talk command must be followed by an appropriate secondary address. See paragraph 3.10.6 for more information on trigger modes.
2. Baseline suppression reduces the dynamic range of the measurement. For example, if the stored baseline value is 100mV on the 200mV range, applying an input of 100mV or more will overrange the instrument even though voltages up to 199.999mV are within the capabilities of the 200mV range with baseline suppression disabled.
3. Setting the range lower than the stored baseline will overrange the instrument.
4. Baseline suppression will be cancelled if enabled when sending the baseline store commands.
5. A command to change function (F) cannot be included in the same command string as the N command, or an "ISbS" (Invalid String with Baseline Store) error will occur.

HP-85 Programming Example—Enter the program below to demonstrate the basic procedure for storing baseline values and using baseline suppression. The program will prompt the operator when to apply baseline and signal voltages. Since the instrument is programmed to the 20V range, voltages should be kept below that level.

PROGRAM	COMMENTS
10 REMOTE 7	Send remote enable.
20 CLEAR	Clear CRT.
30 CLEAR 7	Send DCL.
40 DISP "CONNECT BASELINE VOLTAGE"	Prompt for baseline signal.
50 PAUSE	Wait for operator input.
60 C$="R3F0T1C0X"@GOSUB 170	Program 20V range, zero check off.
70 GOSUB 200	Trigger a reading.
80 C$="N1X"@GOSUB 170	Store baseline value.
90 GOSUB 200	Trigger a reading.
100 DISP A$	Display the reading.
110 DISP "CONNECT SIGNAL VOLTAGE"	Prompt for operator input.
120 PAUSE	Wait for operator input.
130 C$="U1X"@GOSUB 170	Enable baseline suppression.

```
140 GOSUB 200                    Get suppressed
                                 reading.
150 DISP A$                      Display suppressed
                                 reading.
160 END
170 SEND 7; UNL MTA LISTEN       Subroutine to transmit
    6 SCG 1                      command string.
180 OUTPUT 7;C$
190 RETURN
200 SEND 7; UNT MLA TALK 6       Subroutine to get data
    SCG 1                        string.
210 ENTER 7;A$
220 RETURN
```

In this program, the instrument is programmed for the 20V range with zero check off (line 60). The baseline value is then stored (line 80). Baseline suppress is then enabled (line 130), and the suppressed reading is obtained and displayed (lines 140 and 150).

Model 8573 Programming Example—Add the lines below to the modified declaration file (paragraph 3.8.2). The program will prompt the operator to apply baseline and signal voltages. Since the instrument is programmed for the 20V range, signals should be kept below that level.

```
PROGRAM                          COMMENTS

 20 CLS                          Clear screen.
 30 V%=1:CALL IBSRE              Send remote enable.
    (BRD0%,V%)
 40 V%=&H102:CALL IBPOKE         Disable timeouts.
    (BRD0%,V%)
 50 CALL IBCLR(M619%)            Send SDC.
 60 PRINT"CONNECT BASE-          Prompt for operator
    LINE, PRESS KEY"             input.
 70 A$=INKEY$:IF A$=""           Wait for operator
    THEN 70                      input.
 80 CMD$="R3F0T1C0X":CALL        Program 20V range,
    IBWRT(M619%,CMD$)            zero check off.
 90 RD$=SPACE(20)                Define reading input
                                 buffer.
100 CALL IBRD(M619%,RD$)         Trigger a reading.
110 CMD$="N1X":CALL              Store baseline value.
    IBWRT(M619%,CMD$)
120 RD$=SPACE$(20)               Define reading input
                                 buffer.
130 CALL IBRD(M619%,RD$)         Get a reading.
140 PRINT RD$                    Display the reading.
150 PRINT "APPLY SIGNAL,         Prompt for operator
    PRESS KEY"                   input.
160 A$=INKEY$:IF A$=""           Wait for operator
    THEN 160                     input.
170 CMD$="U1X":CALL              Enable baseline sup-
    IBWRT(M619%,CMD$)            pression.
180 RD$=SPACE$(20)               Define reading input
                                 buffer.
190 CALL IBRD(M619%,RD$)         Get a reading.
200 PRINT RD$                    Display reading.
210 V%=0:CALL IBONL              Close instrument file.
    (M619%,V%)
220 CALL IBONL(BRD0%,V%)         Close board file.
```

In the above program, the instrument is programmed for the 20V range with zero check off (line 80), and the baseline value is stored (line 110). The baseline suppression mode is then enabled (line 170), and a suppressed reading is then obtained and displayed (lines 190 and 200).

3.10.9 Data Buffer Storage (Q)

The data store command options enter the data buffer mode and allow 10-50 readings in increments of 10 to be stored within the internal buffer. Note that only one buffer is used for both channels; to fill the buffer with data from a specific channel, send the secondary address for that channel with the data buffer command. These commands include:

Q0=Buffer disabled.
Q1=Store 10 readings.
Q2=Store 20 readings.
Q3=Store 30 readings.
Q4=Store 40 readings.
Q5=Store 50 readings.

Upon power up, or after a DCL or SDC, the buffer will be in the Q0 (disabled) mode.

Once buffer storage has been enabled, subsequent readings for both channels will come from the buffer until all stored readings have been accessed. To disable the buffer without requesting all stored readings, simply send Q0X. The normal reading mode will then be restored.

NOTES:

1. Once the data storage command is given, an appropriate trigger should be given to start buffer storage. For example, in the T0 mode (continuous on talk) send the instrument's talk address followed by the appropriate secondary address.
2. The instrument may be programmed to generate an SRQ when the buffer is full, as described in paragraph 3.10.10.
3. In a one-shot trigger mode, one reading will be stored in the buffer with each trigger stimulus.

4. The buffer cannot be used with the T5 (one-shot on X) trigger mode. In the T5 mode, an X character is necessary to fill each buffer location. However, when the X character is sent, the instrument will update the output buffer and then immediately clear it; therefore, the storage buffer will never fill under these conditions. The same limitations do not apply to the T4 mode since only a single X character is necessary to begin the conversion process.

HP-85 Programming Example—Enter and run the program below to demonstrate data storage buffer operation.

```
PROGRAM                          COMMENTS

 10 REMOTE 7                     Send remote enable.
 20 CLEAR                        Clear CRT.
 30 CLEAR 7                      Send DCL.
 40 SEND 7; UNL MTA LISTEN       Address instrument to
    6 SCG 1                      listen, channel A.
 50 OUTPUT 7;"M1Q5C0X"           Program for SRQ, 50
                                 buffer readings, zero
                                 check off.
 60 SEND 7; TALK 6 SCG 1         Trigger instrument.
 70 STATUS 7,2;S                 Check interfaced status.
 80 IF NOT BIT(S,5)THEN 70       Wait for SRQ.
 90 FOR I=1 TO 50                Loop for all 50
                                 readings.
100 SEND 7; UNT MLA TALK 6       Address instrument to
    SCG 1                        talk.
110 ENTER 7;A$                   Get buffer reading from
                                 instrument.
120 DISP A$                      Display buffer reading.
130 NEXT I                       Loop back for next
                                 reading.
140 END
```

The above program sets up the instrument to generate an SRQ after all 50 readings have been taken (lines 40 and 50). Since a secondary address of 1 is used in line 40, channel A is the selected channel. Lines 70 and 80 provide a status check on the interface SRQ line. In effect, the computer stays in this loop until the Model 619 generates the SRQ when all 50 readings are stored in the buffer.

Lines 90-130 form a simple loop that requests the 50 readings from the instrument. As readings are requested, they are displayed on the computer CRT.

Model 8573 Programming Example—Add the lines below to the modified declaration file (paragraph 3.8.2) to demonstrate basic buffer operation.

```
PROGRAM                          COMMENTS

 20 CLS                          Clear screen.
 30 V%=1:CALL IBSRE              Send remote enable.
    (M619%,V%)
 40 CALL IBCLR(M619%)            Send SDC to 619.
 50 CMD$="M1Q5C0X":CALL          Turn on SRQ, buffer 50
    IBWRT(M619%,CMD$)            readings, turn off zero
                                 check.
 60 CMD$=CHR$(&H46)+             Talk and secondary ad-
    CHR$(&H61)                   dress string.
 70 CALL IBCMD                   Address 619 to talk to
    (BRD0%,CMD$)                 trigger instrument.
 80 MASK%=&H1000:CALL            Wait for SRQ.
    IBWAIT(BRD0%,MASK%)
 90 FOR I=1 TO 50                Loop for all 50
                                 readings.
100 RD$=SPACE$(20)               Define reading input
                                 buffer.
110 CALL IBRD(M619%,RD$)         Get buffer reading.
120 PRINT RD$                    Display buffer reading.
130 NEXT I                       Loop back for next
                                 reading.
140 V%=0:CALL IBONL              Close instrument file.
    (M619%,V%)
150 CALL IBONL(BRD0%,V%)         Close board file.
```

In this program, the instrument is programmed for 50 buffer readings and to generate an SRQ when all 50 readings have filled the buffer (line 50). The computer then waits for the SRQ to occur (line 80), and then loops 50 times, requesting and displaying a buffer location each time it goes through the loop (lines 90-130).

3.10.10 SRQ Mode (M) and Status Byte Format

The SRQ command enables and disables the Model 619 SRQ mode. Once the instrument generates an SRQ, the status byte can be checked to determine if the Model 619 was the instrument that asserted SRQ, and if so, what conditions caused it to do so. SRQ command options include:

M0=SRQ disabled
M1=SRQ enabled

Upon power up, or after a DCL or SDC, the SRQ mode will be disabled.

Status Byte Format—The status byte contains information relating to data and error conditions within the instrument. The general format of the status byte is shown in Table 3-20, along with the various conditions associated with the byte.

Bit 7 (D7) provides a means for determining if SRQ was asserted by the Model 619. If this bit is set, service was requested by the instrument. The status of bit 6 (D6) determines the meanings of bits D1-D4, as outlined in the table. To determine the meaning of D1-D4, simply add up the decimal equivalents for those bits that are set to 1, and read the condition from the table.

Table 3-20. Status Byte Format

D8	D7	D6	D5	D4	D3	D2	D1
128	64	32	16	8	4	2	1
0	1/0	1/0	0	1/0	1/0	1/0	1/0

DECIMAL WEIGHTING

D6: 1 = Error
0 = Non-error

See below

D7: 1 = SRQ by 619
0 = SRQ not by 619

D6 = 1(Error)

Value (D1-D4)	Meaning	Display
0	Illegal device-dependent command.	IddC
1	Illegal device-dependent command option.	IddCO
2	Attempt to program when not in remote.	no rn
3	No zero check with 2A.	no 2AC
4	No zero correct without zero check.	Corr IL
6	No autorange in this range.	no AU
8	Invalid string with Baseline Store.	ISbS

D6 = 0 (Non error):

Value (D1-D4)	Meaning	Display
0	Normal reading	—
1	Overflow reading	OFLO
5	Buffer full	—

The status byte is obtained from the instrument by using the following typical serial polling sequence:

1. The controller places ATN true.
2. The controller places the SPE (Serial Poll Enable) command on the bus.
3. The instrument is addressed to talk.
4. The correct secondary address byte for serial polling ($66) is then placed on the bus.
5. The controller places ATN false.
6. The instrument places the status byte on the bus to be read by the controller.
7. The controller places ATN true.
8. The controller then sends the SPD (Serial Poll Disable) command to end the serial polling sequence.

NOTE:

1. The status byte should be read within 100msec of the talk SPE sequence or the value will reset to default conditions.
2. Once the instrument has asserted SRQ, the status byte should be read to clear the SRQ line. Otherwise, the instrument will continuously assert SRQ.

HP-85 Programming Example—The program below may be used to demonstrate the basic procedure for enabling SRQ, and obtaining and displaying the status byte in binary form.

```
PROGRAM                          COMMENTS
10 REMOTE 7                      Send remote enable.
20 CLEAR 7                       Send DCL.
30 CLEAR                         Clear CRT.
40 C$="M1X"@GOSUB 160            Enable SRQ.
50 C$="F9X"@GOSUB 160            Attempt to program il-
                                 legal command option.
60 STATUS 7,2;S                  Check bus status.
70 IF NOT BIT(S,5)               If SRQ is not asserted, go
   THEN 60                       back and wait.
80 SEND 7; UNT MLA               Address 619 to talk,
   TALK 6 SCG 6                  secondary address for
                                 serial polling.
90 S=SPOLL(7)                    Serial poll the 619.
100 DISP "D8 D7 D6 D5            Display bit positon
    D4 D3 D2 D1"
110 FOR I=7 TO 0                 Loop eight times.
    STEP -1
120 DISP BIT(S,I);               Display the bit position.
130 NEXT I
140 DISP
150 END
160 SEND 7; UNL MTA              Subroutine to send com-
    LISTEN 6 SCG 1               mand.
170 OUTPUT 7;C$
180 RETURN
```

In this program, the SRQ mode is enabled (line 40), and an attempt is made to program an illegal command option (line 50). Interface status is checked for SRQ (lines 60 and 70), after which the program serial polls the Model 619 (lines 80 and 90). Note that a secondary address of 6 is used to as part of the serial polling sequence. The binary bit positions are then displayed (lines 100-130). In this example, D7 (SRQ), D6 (error), and D1 are set while the remaining bit positions in the status byte are cleared.

Model 8573 Programming Example—Add the lines below to the modified declaration file (paragraph 3.8.2) to demonstrate SRQ and serial poll operation.

```
PROGRAM                                  COMMENTS
 20 CLS                                  Clear screen.
 30 V%=1:CALL IBSRE                      Send remote enable.
    (BRD0%,V%)
 40 CALL IBCLR(M619%)                    Send SDC.
 50 C$="M1X":CALL IBWRT                  Enable SRQ.
    (M619%,C$)
 60 C$="F9X":CALL IBWRT                  Attempt to program il-
    (M619%,C$)                           legal command option.
 70 M%=&H1000:CALL                       Wait for SRQ.
    IBWAIT(BRD0%,M%)
 80 V%=&H66:CALL IBSAD                   Change secondary ad-
    (M619%,V%)                           dress for serial poll.
 90 CALL IBRSP                           Serial poll the 619.
    (M619%,SB%)
100 V%=&H61:CALL IBSAD                   Restore secondary ad-
    (M619%,V%)                           dress parameter.
110 MASK%=128                            Initial mask value.
120 PRINT "D8 D7 D6 D5                   Display bit positions.
    D4 D3 D2 D1"
130 FOR I= 1 TO 8                        Loop eight times.
140 IF (MASK% AND SB%)                   Print bit position.
    THEN PRINT "1 "; ELSE
    PRINT "0 ";
150 MASK%=MASK%/2
160 NEXT I                               Go back and do next bit.
170 V%=0:CALL IBONL                      Close instrument file.
    (M619%,V%)
180 CALL IBONL                           Close board file.
    (BRD0%,V%)
```

SRQ is enabled (line 50), and an attempt is made to program illegal command option (line 60). The program waits for the Model 619 to generate an SRQ (line 70), and then serial polls the instrument (lines 80 and 90). Note that the Model 8573 software is changed to use an absolute secondary address value of $66 to serial poll the instrument. The bits in the status byte are then displayed in binary form (lines 110-160).

3.10.11 Filter (P)

The filter command performs essentially the same function as the front panel FILTER button. When the filter is enabled, an additional 25dB of line frequency filtering is added. Fiter commands include:

P0=Filter disabled
P1=Filter enabled

Upon power up, or after a DCL or SDC command, the instrument will be in the P0 (filter disabled) mode.

HP-85 Programming Example—Enter the statements below to enable the filter:

```
REMOTE 7 (END LINE)
SEND 7; UNL MTA LISTEN 6 SCG 1 (END LINE)
OUTPUT 7;"P1X" (END LINE)
```

When the third statement above is executed, the Model 619 FILTER indicator turns on with the instrument set for channel A. The SCG parameter can be changed to 2 for channel B.

Model 8573 Programming Example—Enter the following statements to enable the filter:

```
V%=1:CALL IBSRE(M619%,V%) (return)
CMD$="P1X":CALL IBWRT(M619%,CMD$) (return)
```

Note that the FILTER indicator turns on when the second statement is executed.

3.10.12 Terminator (Y)

The terminator sequence that marks the end of the instruments data string can be programmed by sending the Y command followed by an appropriate ASCII character. The default terminator is the commonly-used carriage return, line feed (CR LF) sequence (CR=ASCII 13, LF=ASCII 10). The terminator will assume this default value upon power up, or after a DCL or SDC.

Table 3-21 summarizes terminator commands that can be used with the Model 619. In addition to the DEL, CR and LF characters, any other ASCII character except for those letters reserved for commands may be used. Each channel can be programmed for a different terminator, if desired.

Table 3-21. Data Terminators

Y Command	Function
Y <DEL>	No terminator
Y <CR>	<LF> <CR> dual terminators
Y <LF>	<CR> <LF> dual terminators
Y <CHAR>	CHAR any 8 bit ASCII value except reserved letters E, R, M, T, D, Q, Y, S, P, Z, N, U, X
Pwr ON/DCL/SDC	Default Y <LF>
Note: <CR> = OD_H <LF> = OA_H	

When a controller inputs data from the instrument, it frequently relies on the default terminator sequence to end the input sequence. Thus, programming a non-standard terminator may cause the input sequence to hang unless other programming steps are taken. Terminating on EOI is another way to end the sequence since the Model 619 sends EOI with the last byte out (except in D1, binary mode).

HP-85 Programming Example—To suppress the terminator entirely, send the following statements:

```
REMOTE 7 (END LINE)
SEND 7; UNL MTA LISTEN 6 SCG 1 (END LINE)
OUTPUT 7; "Y"; CHR$(127); "X" (END LINE)
```

Model 8573 Programming Example—Type in the following statements to suppress the terminator completely:

```
V%=1:CALL IBSRE(BRD0%,V%) (return)
CMD$="Y"+CHR$(127)+"X" (return)
CALL IBWRT(M619%,CMD$) (return)
```

3.11 MACHINE STATUS WORDS

The Model 619 has two status words that can be accessed over the bus to determine various operating modes such as function and range. Each status word is made up of 16 ASCII characters with the format shown in Figure 3-10. Note that a separate status word is available for each channel and is accessed with the appropriate secondary address as follows:

Channel A status, secondary address 3 ($63)
Channel B status, secondary address 4 ($64)

To access machine status, the controller need only address the instrument to talk in the normal manner, followed by the correct secondary address for the channel being accessed, as indicated previously. The instrument will then transmit the status word, followed by the programmed terminator sequence (default is CR LF), as requested by the controller.

Most of the bytes in the channel A and channel B status words have essentially the same meanings, as outlined in Table 3-22. The exception is the byte 14 value which gives the programmed line frequency in the channel A status word, and the buffer status in the channel B status word.

NOTE

The instrument must be in the Q0 (buffer disabled) mode in order to obtain machine status.

HP-85 Programming Example—Use the program below to access channel A or channel B machine status. After prompting for the desired channel, the program sets the secondary address to access channel A or channel B, and then displays the machine status on the computer CRT.

```
PROGRAM                          COMMENTS
10 REMOTE 7                      Send remote enable.
20 CLEAR                         Clear CRT.
30 DISP "CHANNEL (A OR B)"       Prompt for channel.
40 INPUT A$                      Input channel.
50 IF A$="A" THEN S1=3@          If channel A, set secon-
   GOTO 80                       dary address parameter.
60 IF A$="B" THEN S1=4@          If channel B, set secon-
   GOTO 80                       dary address parameter.
70 GOTO 30                       If not channel A or B,
                                 prompt again.
80 SEND 7; UNT MLA TALK 6        Address 619 to talk,
   SCG S1                        secondary address for
                                 machine status.
90 ENTER 7;B$                    Input machine status.
100 DISP B$                      Display machine status.
110 GOTO 30                      Do again.
120 END
```

MACHINE STATUS Ch.A (SECONDARY ADDRESS 63_H)

0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14	+15
ZERO CORRECT	FILTER	ZERO CHECK	FUNCTION	RANGE	MODE	RATE TYPE	0	TRIGGER	BASELINE STORE	BASELINE SUPPRESS	AUTO RANGE	INT PERIOD	TERMI-NATOR	50/60 Hz	*READING TO AVE.
Z	P	C	F	R	M	S	D	T		U		Y			

MACHINE STATUS Ch. B (SECONDARY ADDRESS 64_H)

0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14	+15
ZERO CORRECT	FILTER	ZERO CHECK	FUNCTION	RANGE	MODE	RATE TYPE	DATA	TRIGGER	BASELINE STORE	BASELINE SUPPRESS	AUTO RANGE	INT PERIOD	TERMI-NATOR	0	*READING TO AVE.
Z	P	C	F	R	M	S	D	T	N	U		Y	Q		

FOR EXAMPLE: AFTER POWER ON, CHANNEL A STATUS WOULD READ IN 60Hz OPERATION IN ASCII: 0010403000004:02.
IN 50Hz OPERATION: 0010403003008:?2

Figure 3-10. Machine Status Format

Model 8573 Programming Example—Add the lines below to the modified declaration file (paragraph 3.8.2) to demonstrate the basic method for obtaining machine status. The program will first prompt which channel is desired. At this prompt, simply type in the channel, or type in 'EXIT' to end the program. The secondary address will then be set to the correct value for the selected channel. At the exit point, the secondary address is restored to the value required to access normal data on channel A.

```
PROGRAM                                  COMMENTS
 20 CLS                                  Clear screen.
 30 V%=1:CALL IBSRE                      Send remote enable.
    (BRD0%,V%)
 40 INPUT "CHANNEL (A,B                  Input channel.
    or EXIT)";A$
 50 IF A$="EXIT" THEN 140
 60 IF A$="A" THEN                       If channel A selected, set
    V%=&H63:GOTO 90                      secondary address.
 70 IF A$="B" THEN                       If channel B selected, set
    V%=&H64:GOTO 90                      secondary address.
 80 GOTO 40                              If neither A nor B, prompt
                                         again.
 90 CALL IBSAD                           Set secondary address for
    (M619%,V%)                           machine status.
100 RD$=SPACE$(20)                       Define reading input buf-
                                         fer.
110 CALL IBRD                            Get machine status.
    (M619%,RD$)
120 PRINT RD$                            Display machine status.
130 GOTO 40
140 V%=&H61:CALL IBSAD                   Return to default secon-
    (M619%,V%)                           dary address.
150 V%=0:CALL IBONL                      Close instrument file.
    (M619%,V%)
160 CALL IBONL                           Close board file.
    (BRD0%,V%)
```

3.12 DATA TRANSMISSION TIMES

The time period necessary for the Model 619 to take a reading depends on a variety of factors including:

1. The time it takes the Model 619 to respond to a command from the controller.
2. The analog settling time. Settling times within 0.1% are given in the specifications at the front of this manual.
3. The time from the trigger to the first byte available. This time period depends on the selected rate and trigger modes, as summarized in Table 3-23. If a range or function change takes place, additional time must be alloted, as indicated in Table 3-24. Times for continuous trigger modes are listed in Table 3-25.
4. The time necessary to transmit data over the bus. This time period depends on the data format used. In the ASCII (D0) mode, 16 to 18 bytes must be transmitted, while only four bytes need be transmitted in the binary (D1) mode. Controller speed may also affect transmission times. The Model 619 can transmit data as fast as 57μsec per byte; however, in the S0 mode, a 6msec delay occurs with each string. If the controller waits more than 5.2msec before obtaining the next byte, the Model 619 may delay the completion of the handshake by up to 3msec.

Table 3-22. Machine Status Byte Definitions

Byte 0 Zero Correct	Byte 1 Filter
chA: 0 = Zero Correct off (Z0)* 1 = Zero Correct on (Z1) chB: Same as chA	chA: 0 = Filter off (P0)* 1 = Filter on (P1) chB: Same as chA
Byte 2 Zero Check	**Byte 3 Function**
chA: 0 = Zero Check off (C0) 1 = Zero Check on (C1)* chB: Same as chA	chA: 0 = Volts (F0)* 1 = Amps (F1) 2 = Ohms (F2) chB: Same as chA
Byte 4 Range	**Byte 5 MOde**
chA: 0 = Autorange 1 = Range 1 (R1) 2 = Range 2 (R2) 3 = Range 3 (R3) 4 = Range 4 (R4)* 5 = Range 5 (R5) 6 = Range 6 (R6) 7 = Range 7 (R7) 8 = Range 8 (R8) 9 = Range 9 (R9) : = Range 10 (R:) chB: Same as chA	chA: 0 = No SRQ (M0)* 1 = SRQ (M1) chB: Same as chA
Byte 6 Rate Type	**Byte 7 Data**
chA: 0 = Rate (S0) 1 = Rate (S1) 2 = Rate (S2) 3 = Rate (S3)* 4 = Rate (S4) 5 = Rate (S5) 6 = Rate (S6) 7 = Rate (S7) 8 = Rate (S8) 9 = Rate (S9) chB: Same as chA	chA: 0 = ASCII (D0)* 1 = Binary (D1) chB: Same as chA
Byte 8 Trigger	**Byte 9 Baseline Store**
chA: 0 = Continuous on Talk (T0)* 1 = One-Shot on Talk (T1) 2 = Continuous on GET (T2) 3 = One-Shot on GET (T3) 4 = Continuous on X (T4) 5 = One-Shot on X (T5) chB: Same as chA	chA: 0 = No Store (N0)* 1 = Store Reading (N1) chB: Same as chA
Byte 10 Baseline Suppress	**Byte 11 Auto Range**
chA: 0 = Suppress off (U0) 1 = Suppress on (U1) chB: Same as chA	chA: 0 = Non-Autorange* ? = Autorange chB: Same as chA

Table 3-22. Machine Status Byte Definitions (Cont.)

Byte 12 Integration Period	Byte 13 Terminator
chA: 4 = 16.66msec 5 = 4.1msec 8 = 20msec 9 = 100msec chB : Same as chA	chA: ? = Y(DEL) = = Y(CR) : = Y(LF)* chB: Same as chA
Byte 14 Frequency or Buffer State	**Byte 15 No. Readings to Average**
chA 50/60Hz** 0 = 60Hz ? = 50Hz chB: Buffer State 1 = Buffer no readings (Q0)* : = Buffer 10 readings (Q1) 4 = Buffer 20 readings (Q2) >= Buffer 30 readings (Q3) 8 = Buffer 40 readings (Q4) 2 = Buffer 50 readings (Q5)	chA: 0 = 1 1 = 2 2 = 4* 3 = 8 4 = 16 5 = 32 chB: Same as chA

*Default conditions. Power up or DCL, SDC.
**Depends on internally programmed line frequency.

Table 3-23. One Shot Times (Typical) in Milliseconds

	T1*		T3**		T5**	
Rate	BIN	ASCII	BIN	ASCII	BIN	ASCII
S0	17	28	18	28	40	40
S1	29	33	30	32	43	36
S2	72	76	73	75	87	83
S3	155	160	156	164	170	180
S4	108	112	108	116	122	122
S5	305	305	305	320	320	320
S6	700	700	700	730	720	720
S7	1500	1500	1500	1540	1540	1500
S8	3150	3100	3100	3200	3100	3100
S9	6300	6200	6300	6400	6200	6200

* ATN ↑ to DAV ↓

** ATN ↑ to SRQ ↓

Table 3-24. Typical Trigger to First Byte Times when Changing Modes

Change	S0	S1
Function	3msec	3msec
Range	3msec	3msec
Channel	42msec	42msec
Integration (S0-S1)		114msec
(S1-S0)	48msec	

Table 3-25. Continuous Times (Typical) in Milliseconds

Rate	T0, T2 and T4	
	BIN	ASCII
S0	13	13
S1	41.5	42
S2	81	81
S3	160	160
S4	210	210
S5	412	430

SECTION 4
APPLICATIONS

4.1 INTRODUCTION

Applications for the Model 619 are many and varied and will depend on the user's needs. Basically, the Model 619 can be used to make many of the same measurements in the range of ordinary DMMs; however, special characteristics such as high input resistance and high sensitivity give the instrument much better capabilities than those of the ordinary DMM.

For example, the typical input resistance for an ordinary DMM is on the order of 10MΩ. In contrast, the Model 619 has an input resistance of greater than 20TΩ ($2 \times 10^{13}\Omega$). The Model 619 can detect currents as low as 10fA (10^{-14} A), while a typical DMM might be limited to current measurements in the μA range.

This section will discuss some possible applications for the Model 619 Electrometer. Keep in mind that these examples are only representative of what is possible with this highly sophisticated instrument, and by no means exhaust the possible uses for the unit.

4.2 INSULATION RESISTANCE MEASUREMENTS

At the moderate impedance levels of many circuits, insulation resistance is seldom a consideration, as it is generally many orders of magnitude above the highest impedance encountered in the remainder of the circuit. At very high impedance levels, however, insulation resistance can be a consideration, since it can lower effective circuit impedance considerably. Since typical insulation resistances run in the range of $10^{10} - 10^{16}\Omega$, their values lie above the measurement range of ordinary instruments. The high resistance measurement range of the Model 619, however, gives it capabilities to measure such high resistances.

A typical test configuration for making insulation resistance measurements is shown in Figure 4-1. Using this method, insulation resistances up to 2TΩ can be measured.

For resistance measurements above $10^{8}\Omega$, or for cables longer than three feet, guarded measurements are recommended, as shown in Figure 4-2. In this case, the Model 6191 adapter is used to apply a guard signal to the inner shield on the connecting cable. The guard is carried through to the inner shield of the test fixture. The inner shield must be insulated from the outer shield, which is a safety shield. Incidentally, a shielded fixture is recommended for both unguarded and guarded configurations for measurements above $10^{7}\Omega$ if stable readings are to be expected (in the unguarded mode, the shield should be connected to input low).

With the constant current method just discussed, the Model 619 can make measurements as high as 2TΩ. However, the insulation resistance of such materials as polyethylene may lie above this range. By using the Model 619 to make resistance measurements with the constant-voltage method, measurement range can be extended considerably.

A typical configuration for using the Model 619 with a Model 230 Voltage Source in this manner is shown in Figure 4-3. Here, the Model 230 Voltage Source is used to force a current, I, through the unknown resistance, R. The insulation resistance can be calculated as follows:

$$R = \frac{V}{I}$$

where I is the current through the resistance as measured by the instrument, and V is the programmed voltage of the Model 230.

For example, assume that the applied voltage is 100V, and the measured current is 1pA. The resistance is calculated as follows:

$$R = \frac{V}{I} = \frac{100}{1pA} = 10^{14}\Omega$$

In addition to the measurement of insulation resistances, this basic method can be used to measure unwanted leakage resistances. For example, leakage resistance between PC board traces and connectors can be made with either of the two methods above, depending on the resistance values involved.

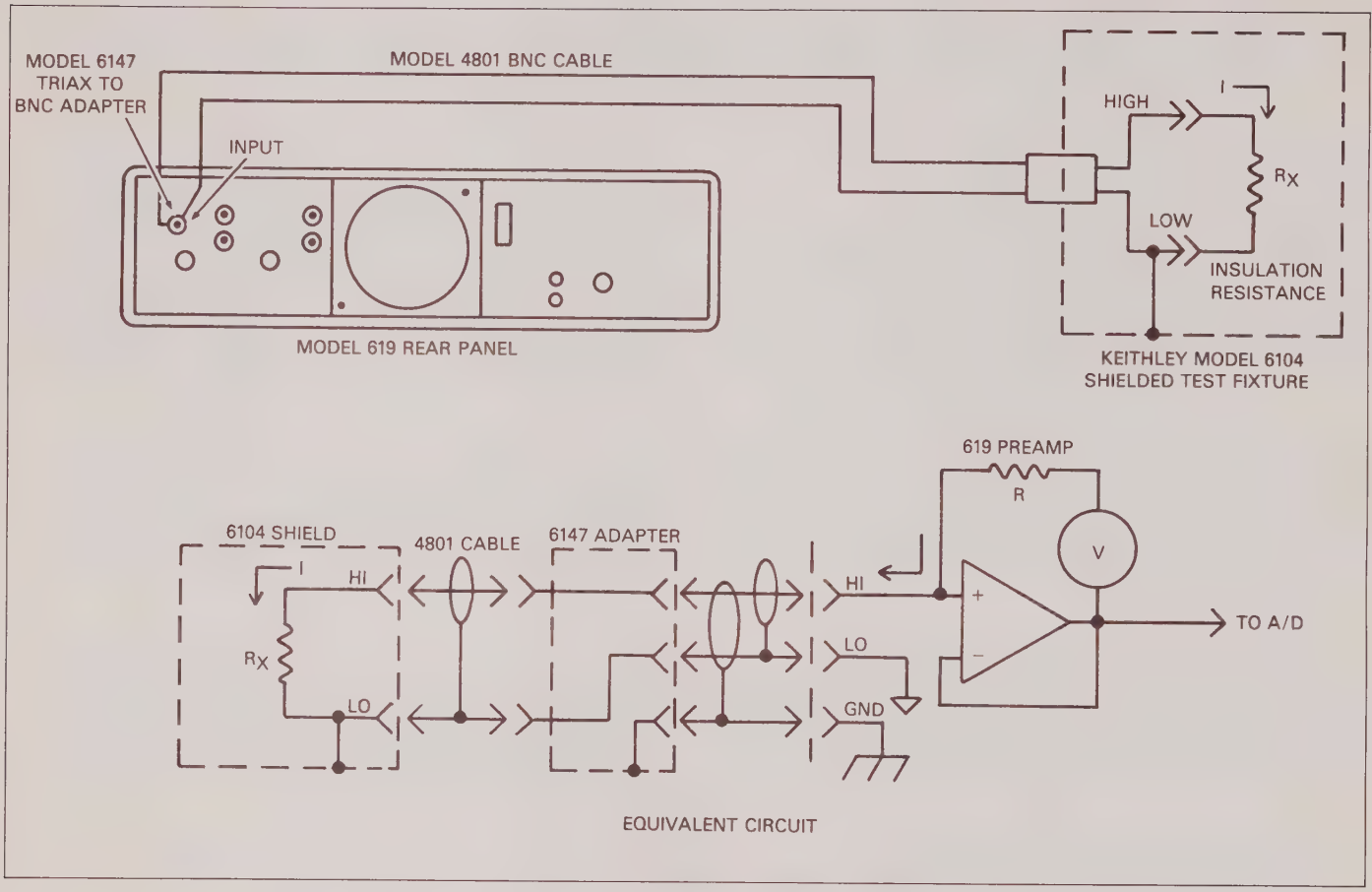


Figure 4-1. Isolation Resistance Measurement (Unguarded)

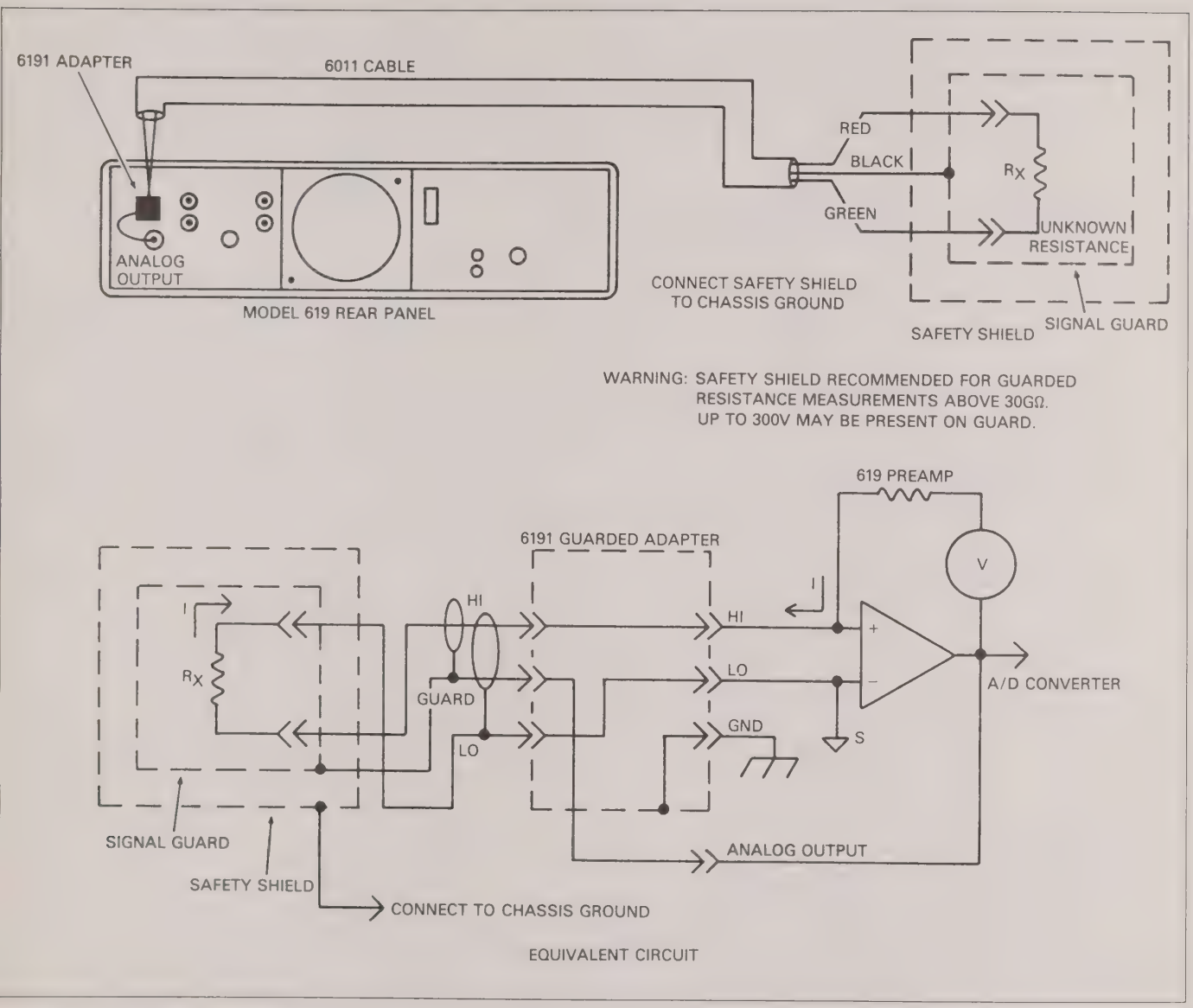


Figure 4-2. Guarded Isolation Resistance Measurements

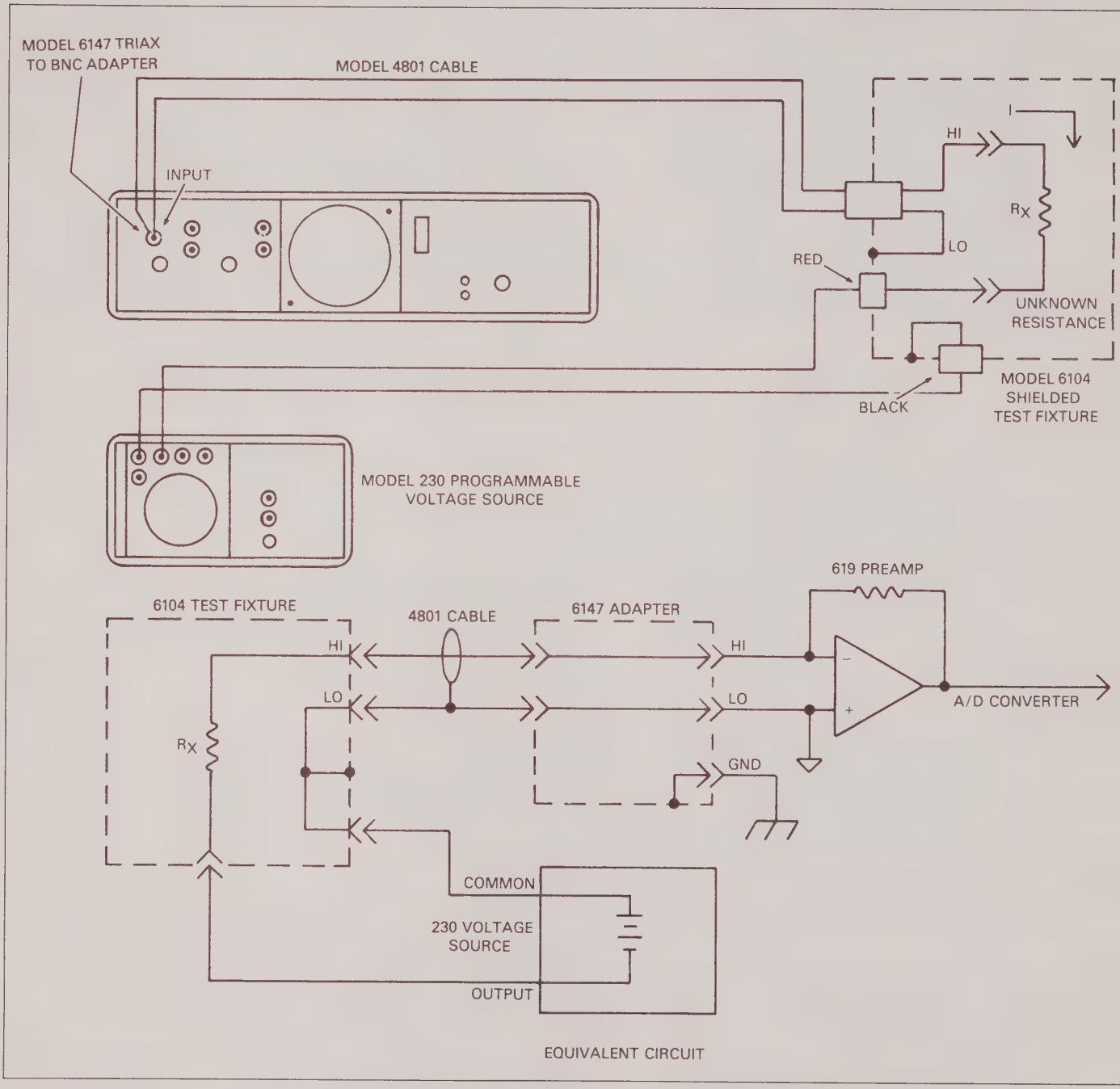


Figure 4-3. Isolation Resistance Measurement Using External Voltage Source

4.3 HIGH IMPEDANCE VOLTMETER

The input resistance of the Model 619 in the volts mode is greater than 20TΩ. Because of this high value, the Model 619 can be used to make voltage measurements in high impedance circuits with a minimum of loading effects on the circuit.

Consider the situation where a circuit designer must measure the gate-to-source voltage of a precision JFET amplifier that has a gate impedance of 100MΩ. Further assume that the required accuracy of this measurement is 1%.

The set-up for this measurement is shown in Figure 4-4. The gate-source voltage is represented by V_{GS}, while the effective gate impedance is represented as R_S. The input resistance of the voltmeter is given as R_{IN}.

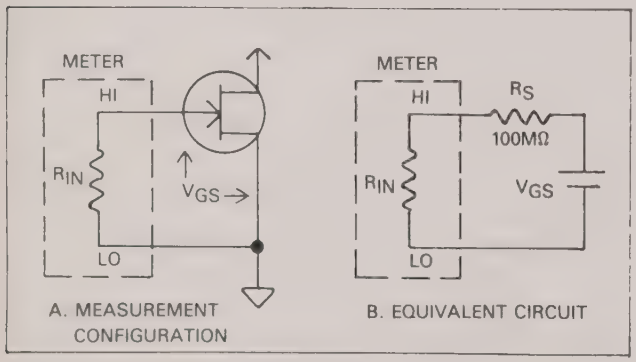


Figure 4-4. Measuring High Impedance Gate Source Voltage

The percent error due to voltmeter loading in this circuit can be given as:

$$\%\text{ERROR} = \frac{R_S}{R_S + R_{IN}} \times 100\%$$

Suppose, for example, a typical DMM with a 10MΩ input resistance were used to make this measurement. The error because of meter loading would be:

$$\%\text{ERROR} = \frac{100\text{M}\Omega}{100\text{M}\Omega + 10\text{M}\Omega} \times 100\% = 91\% \text{ error}$$

Even if a DMM with an input resistance of $10^9\Omega$ were used, the error would still be:

$$\%\text{ERROR} = \frac{100\text{M}\Omega}{100\text{M}\Omega + 1\text{G}\Omega} \times 100\% = 9.1\% \text{ error}$$

Such a large error would not be tolerable in this case because of the 1% accuracy requirement. However, since the Model 619 has an input resistance of 20TΩ, its error in this example would be:

$$\%\text{ERROR} = \frac{100\text{M}\Omega}{100\text{M}\Omega + 20\text{T}\Omega} \times 100\% = 0.0005\% \text{ error}$$

Thus, the input impedance of the Model 619 would be more than adequate for this situation, because the error due to meter loading is substantially better than the required 1% value stated earlier. In addition, the 5½ digit resolution of the instrument allows the designer sufficient precision to make use of the high input impedance.

4.4 LOW-LEVEL LEAKAGE CURRENT MEASUREMENTS

Many devices exhibit low-level leakage currents that may require measurement. Typically, such leakage current might lie in the nA (10^{-9}A) or pA (10^{-12}A) range. The Model 619 is an ideal instrument for such current measurements because it can detect currents as low as 10fA.

An example of a situation requiring low current measurement is shown in Figure 4-5. In this example, the gate leakage current of a JFET is to be measured. Although the device manufacturer may specify the current value, it is often desirable to verify the specification for a particular sample of the device. Then too, the specified leakage current might be at a higher voltage than required. For example, the specified leakage current might be 1nA with an applied voltage of 25V, while that figure might be much less at an operating value of 10V.

To use the Model 619 in this application it will be necessary to apply external voltage with a Model 230 Programmable Voltage Source. The Model 230 could be programmed to the desired value or values, and the leakage current could be measured for each voltage. In this manner, leakage current characterization studies could be performed with a minimum of operator involvement.

As shown in Figure 4-5, a shielded test fixture such as the Keithley Model 6104 should be used to keep the measurement quiet and stable. A good quality low-noise cable, such as the Model 4801 connected through a Model 6147 adapter should be used to connect the current input to the instrument.

Forward and reverse diode currents could be measured in a similar manner. The forward leakage current (measured with the Model 230 set to less than 0.6V) can be measured using the Model 619 without regard to input voltage burden.

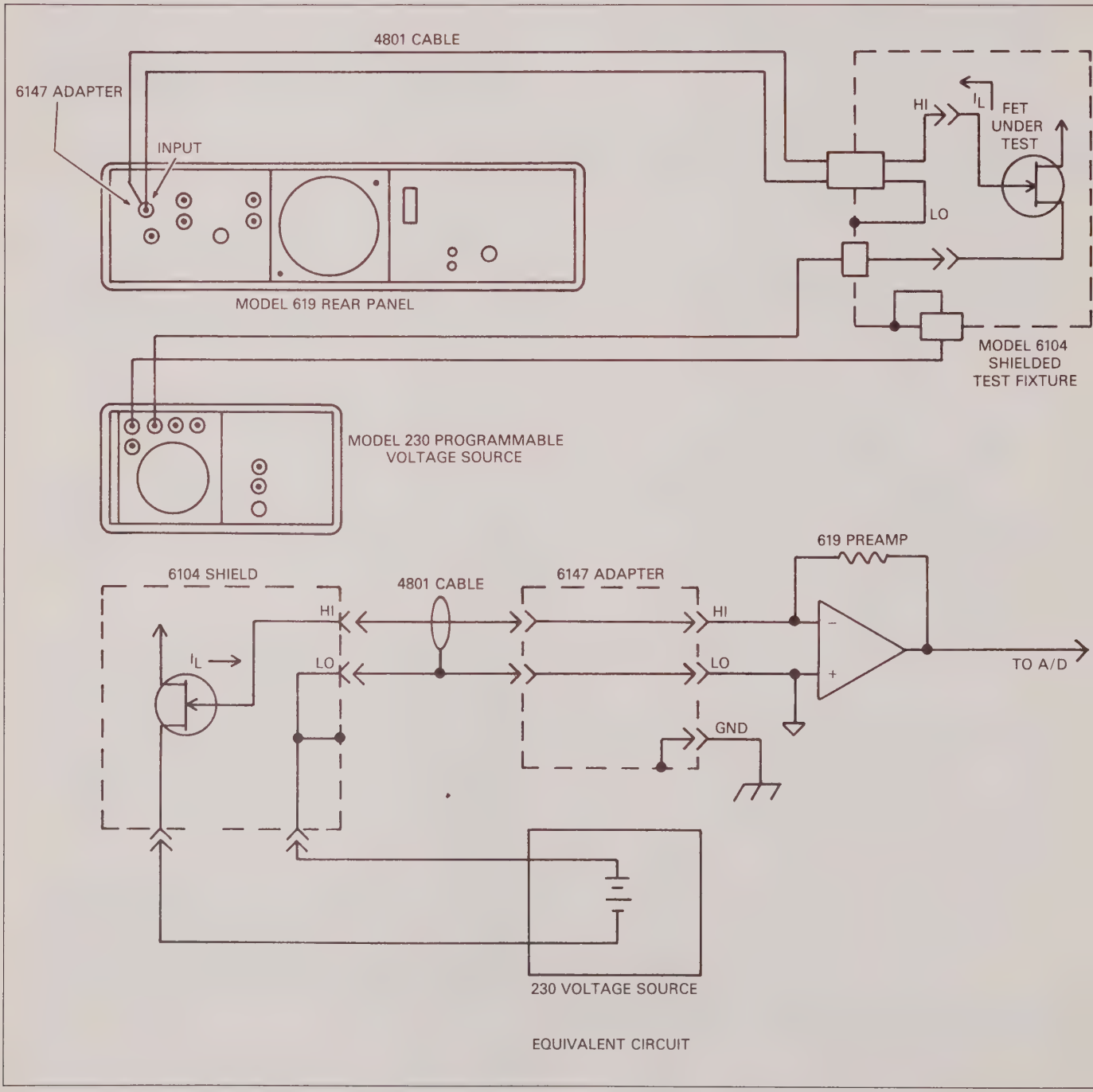


Figure 4-5. Leakage Current Measurement

4.5 DIODE CHARACTERIZATION

When the Model 619 is placed in the ohms mode, constant current values between 100pA and 100μA are available at the INPUT jack high and low terminals, as shown in Table 4-1 (Input high sources the current). These currents can be used to plot the I-V (current-voltage) characteristics over a substantial range.

Table 4-1. Diode Currents

Range	Diode Current
2kΩ, 20kΩ	100μA
200kΩ, 2MΩ	1μA
20MΩ, 200MΩ, 2GΩ	10nA
20GΩ, 2TΩ	100pA

Figure 4-6 shows the basic circuit configuration for using the Model 619 in this manner. A decade current, I, is forced through the diode under test. The current will develop a forward voltage drop, V_F, across the diode. The voltage seen at the analog output will be the product of the displayed resistance and the test current.

Figure 4-7 shows several examples for typical diodes. The curves were drawn from data obtained in the manner just described.

WARNING
Up to 300V may be present between the high and low terminals in ohms.

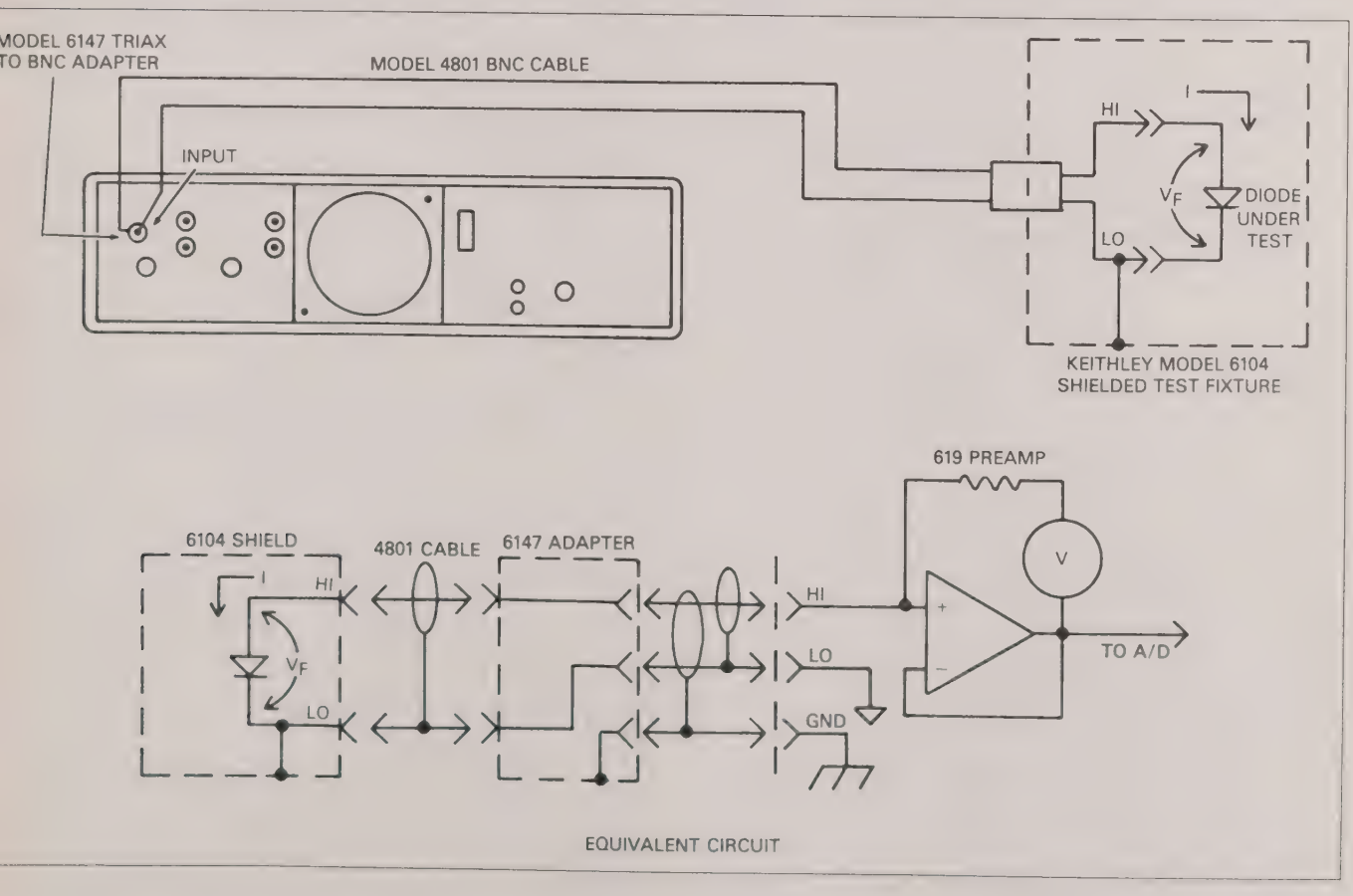


Figure 4-6. Diode Characterization

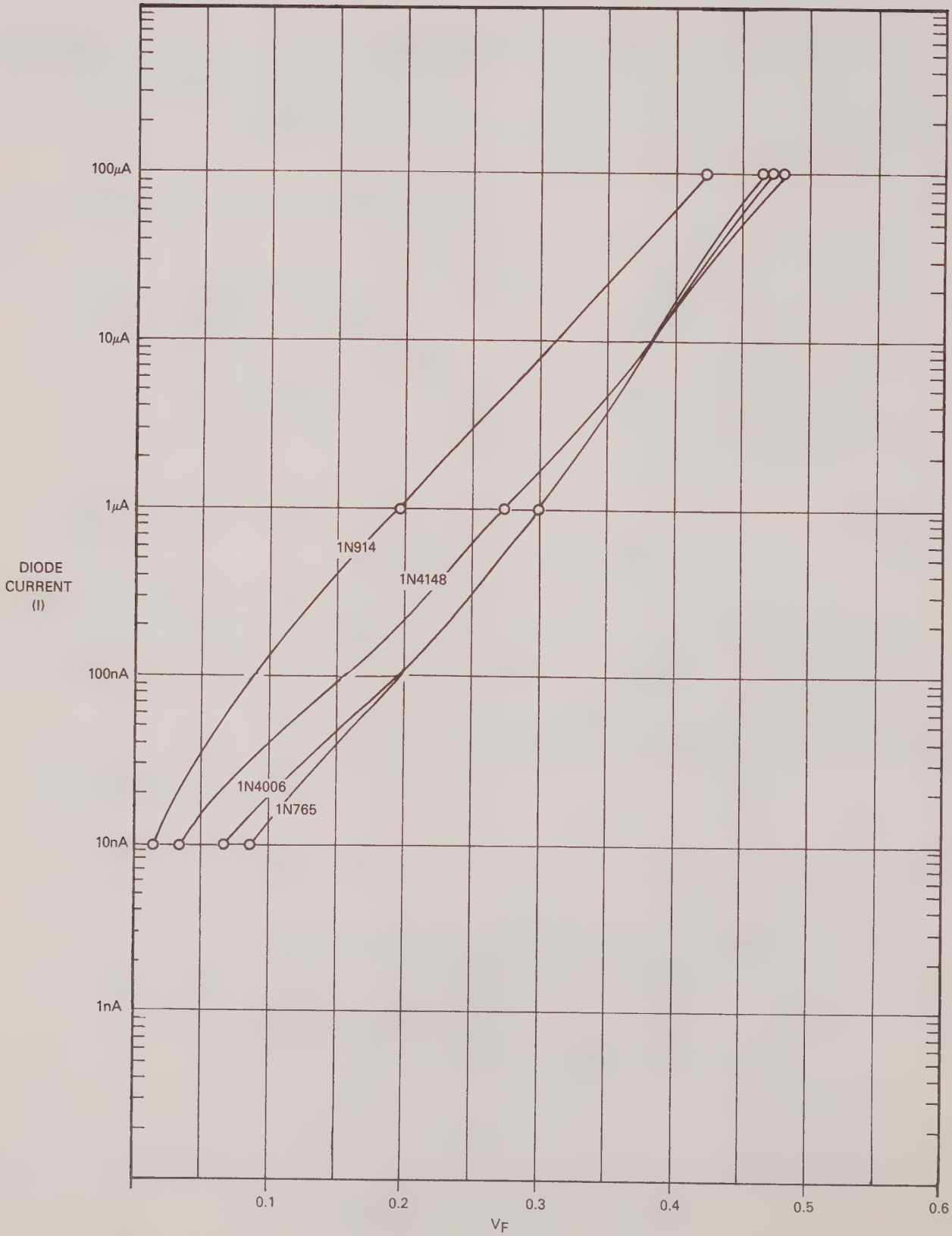


Figure 4-7. Diode Curves

4.6 CAPACITOR LEAKAGE MEASUREMENTS

An important parameter associated with capacitors is their leakage currents. Once the leakage current is known, the insulation resistance can be calculated. Ideally, a capacitor should have no leakage current, and thus infinite leakage resistance. However, capacitors, like all practical devices, are not ideal, so these parameters can become important especially to circuit design and component engineers. The amount of leakage current in a given capacitor depends on its dielectric as well as the applied voltage. Ceramic dielectric capacitors typically have leakage currents in the nA to pA range, while polystyrene and polyester dielectric devices exhibit much lower leakage currents-generally in the fA range. (These values are for test voltages in the 100V range).

The basic configuration for this test is shown in Figure 4-8. The Model 230 Voltage Source is used to impress a voltage across the capacitor, C. The resulting current is then measured by the Model 619.

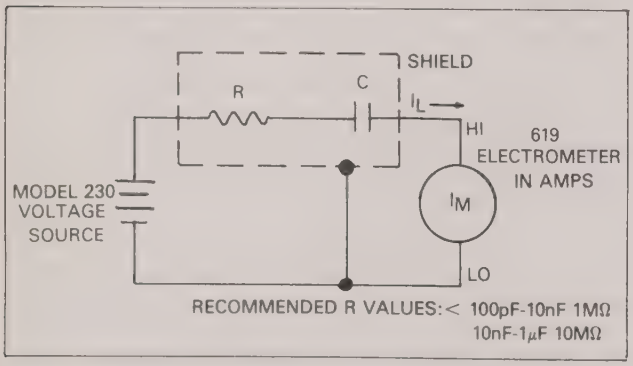


Figure 4-8. Capacitor Leakage Tests

The resistor R is necessary to limit current to a safe value in case the capacitor is shorted, and it also helps to reduce noise. Typically a value of about 1MΩ should be used, although that value can be decreased for larger capacitor values. However, values under 10kΩ are not recommended.

At the start of the test, the Model 619 should be placed in the amps mode and on the 20mA range. The Model 230 Voltage Source is then programmed to the desired voltage, and the output turned on. Once the required soak time has passed, the instrument can be placed in the proper current range to make the current measurement. The soak time is the period necessary to fully charge the capacitor, typically 10RC. Once the test is completed, the voltage source should be turned off to allow the capacitor to discharge.

The leakage current can be directly read from the Model 619 display during the test procedure. If the leakage resistance value is required instead, the resistance can be calculated by dividing the programmed voltage by the measured current.

This basic procedure could be used to test a number of capacitors on an automated basis. A test fixture that holds a number of capacitors could be constructed, and a Keithley Model 705 or Model 706 Scanner could be used to select among the various devices to be tested. For a higher degree of automation, the scanner, the Model 230, and the Model 619 could be controlled from a computer via the IEEE-488 bus. In this way, measurements that would otherwise be tedious and time consuming could be conducted on a more routine basis.

4.7 CAPACITANCE MEASUREMENT

By adding an external feedback capacitor (paragraph 2.11.4), the Model 619 can be used to measure coulombs. Doing so will result in an easy method of measuring capacitance values of capacitors, cables and connections. It is especially useful in cases of cables and connectors because of the small values of charge that can be measured.

The basic method involves using an external Model 230 Voltage Source to apply a step voltage across the capacitor, as shown in Figure 4-9. Since charge is to be measured, the Model 619 should be in external feedback to make the measurement. Just prior to turning on the voltage source, zero check should be disabled and the charge suppressed. Then, turn on the voltage source and note the final charge value.

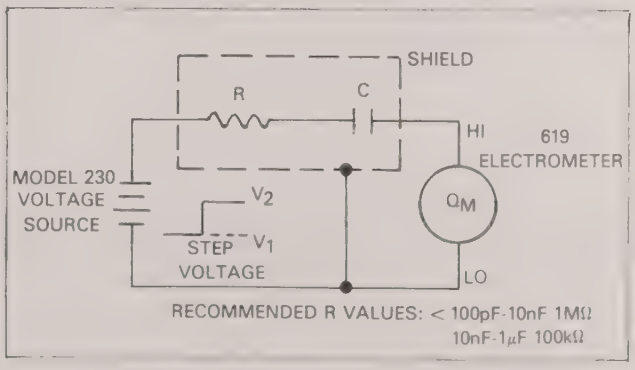


Figure 4-9. Capacitor Measurement

The capacitance can then be computed as follows:

$$C = \frac{\Delta Q}{\Delta V}$$

where:
$\Delta Q = Q_2$ (final charge) $- Q_1$ (initial charge assumed to be 0)
$\Delta V = V_2$ (step voltage) $- V_1$ (initial voltage assumed to be 0)

As an example of the above procedure, assume that an unknown capacitor is to be measured. If the step voltage is 100V, and a ΔQ value of 2nC is obtained, the capacitance value is:

$$C = \frac{2nC}{100V} = 20pF$$

4.8 VOLTAGE COEFFICIENT OF HIGH-MEGOHM RESISTORS

High megohm resistors (above $10^9\Omega$) often exhibit a change in resistance with applied voltage. This resistance change is characterized as the voltage coefficient. The Model 619 can be used with an external voltage source such as the Model 230 to make this type of measurement.

The basic configuration for making voltage coefficient studies is the same as that used to make constant-voltage insulation resistance measurements (Figure 4-3). The voltage, is applied to the resistor under test by the voltage source and the current is measured by the electrometer. The resulting current can then be used to calculate the resistance:

$$R = \frac{V}{I}$$

Two resistance readings at two different voltage values will be required to calculate the voltage coefficient. The voltage coefficient in %/V can then be calculated as follows:

$$\text{Voltage Coefficient (\%/V)} = \frac{100\ (R_2\text{-}R_1)}{R_1(\Delta V)}$$

where:
R_1 is the resistance with the first applied voltage.
R_2 is the resistance with the second applied voltage.
ΔV is the difference between the two applied voltages.

As an example, assume that the following values are obtained:

$R_1 = 1.01 \times 10^{10}\Omega$
$R_2 = 1 \times 10^{10}\Omega$
$\Delta V = 5V$

The resulting voltage coefficient is:

$$\text{Voltage Coefficient (\%/V)} = \frac{100(1 \times 10^8)}{1 \times 10^{10}(5)} = 0.2\%/V$$

Note that the voltage coefficient of a particular device may apply only across the selected voltage range, and may, in fact, vary with different voltage increments in the same approximate range.

4.9 STATIC CHARGE DETECTION

Electrostatic charge is a deficiency or excess of electrons on an ungrounded surface. Such charges are usually generated on poor conductors of electricity such as plastics, synthetic fibers, and paper during handling or processing of these materials. Once these charges accumulate, they do not dissipate readily because of the excellent insulating characteristics of the materials involved.

Static charge build-up can be a problem with integrated circuits, especially with those of the CMOS variety. While these devices, which operate at high impedance levels, often have static protection built in, it is best to properly protect them during transit or storage. For that reason, such ICs are usually shipped and stored in anti-static tubes.

A primary consideration, then, is the degree of static protection afforded by the anti-static tube. A comparison among various tubes can be set up to test the variations in charge build-up as a particular IC slides the length of the tube. The charge value will, of course, be measured by the Model 619. In order to measure charge, the Model 619 must be used in the external feedback mode with a capacitor as the feedback element (see paragraph 2.11.4).

To perform this test, a test fixture called a Faraday cup will be necessary. Such a fixture could be easily constructed from two cans, as shown in Figure 4-10. For example, the outer can be the ubiquitous one-gallon paint can, while the inner cylinder could be one of slightly smaller diameter, such as a quart paint can. The two cans must be insulated from one another. Although, the type of insulator is not all that critical, ceramic or Teflon insulators can be used.

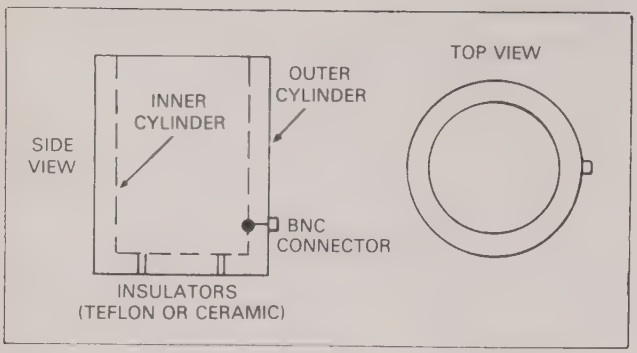


Figure 4-10. Faraday Cup Construction

For convenience, a BNC connector could be mounted on the outside can. The outer, or shield connection will, of course, be connected to the outer can, while the inner conductor should be connected to the inner can.

To perform the test, connect the Model 619 to the Farady cup using a suitable shielded cable, such as Model 4801 BNC cable. A Model 6147 triax-to-BNC adapter will be required to make the connection. With the instrument in the external feedback mode, place a typical IC in the tube to be tested; allow it to slide the full length of the tube and fall into the Farady cup. The amount of charge build up during the test will then be registered on the Model 619.

The test can be repeated with other tubes, as required. In order for the test to be valid, all tubes should be the same length, and the same IC should be used in every case. The tube that generates the smallest static charge as seen on the electrometer is the one with the best anti-static characteristics. The amount of charge seen during this test will depend on many factors, including the type of tube material, tube length, the IC used, as well as the relative humidity. Typical values might be in the 0.5-1nC range for a good anti-static tube, while one without anti-static protection might generate 10 times that amount.

SECTION 5
PERFORMANCE VERIFICATION

5.1 INTRODUCTION

Performance verification may be performed upon receipt of the instrument to ensure that no damage or misadjustment has occurred during transit. Verification may also be performed whenever the accuracy is questioned, or following calibration, if desired.

NOTE

If the instrument is still under warranty (less than 12 months) since date of shipment), and its performance falls outside specifications at any point, contact your Keithley representative or the factory to determine the correct course of action.

5.2 REQUIRED TEST EQUIPMENT

The accuracy of the test equipment should be at least five times better than instrument specifications. The minimum required accuracy ratings of the voltage, current and resistance sources are as follows:

1. Voltage Sources:
   A. 190mV to 1.9V −.002%
   B. 19V to 190V −.003%
2. Current Sources:
   A. 1.9nA to 19nA −.07%
   B. 190nA to 1.9A −.03%
3. Resistance Sources:
   A. 1.9kΩ to 19kΩ −.04%
   B. 190kΩ to 1.9MΩ −.03%
   C. 19MΩ, 190MΩ, 1.9GΩ −.07%
   D. 19GΩ −.2%
   E. 190GΩ −.8%
   F. 1.5TΩ −2%

If the accuracy of the test equipment is not at least five times better than the instrument specifications, additional allowance must be made in the readings obtained.

5.3 ENVIRONMENTAL CONDITIONS

All measurements should be made at an ambient temperature within the range of 18° to 28°C (65° to 82°F) and a relative humidity of less than 70%.

5.4 INITIAL CONDITIONS

Before beginning the verification procedure the instrument must meet the following conditions:

1. If the instrument has been subjected to extremes of temperature, allow sufficient time for internal temperature to reach the normal operating environmental conditions specified in paragraph 5.3. Typically, it takes one hour to stabilize a unit that is 10°C (18°F) out of the specified temperature range.
2. Turn on the Model 619 and allow it to warm up for one hour.

5.5 VERIFICATION LIMITS

The limits for the various verification procedures in this section are given as a variation in allowable readings. These limits are based on the specifications given at the front of this manual and do not include test equipment tolerance. As stated in paragraph 5.2, if the test equipment tolerance is not at least five times better than equivalent Model 619 specifications, additional allowances must be made in the reading limits.

5.6 INPUT CONNECTIONS

All input signals (except for the 2A input) are to be applied to the INPUT connector on the channel A or channel B 6194 Electrometer Module. Use only low-noise triaxial cable, such as the supplied Model 6011, to make the connections. All input connectors must be kept clean to minimize input impedance deterioration that could give erroneous results. If in doubt as how to go about connecting the various verification sources to the Model 619, refer to Section 2 for more detailed information.

5.7 VERIFICATION PROCEDURES

Use the following procedures to verify the basic accuracy of the Model 619. If the instrument is out of specification at any point, a complete calibration should be performed as described in Section 7. However, if the instrument is still under warranty, contact your Keithley representative or the factory immediately.

NOTE

Performance verification should be performed by qualified personnel using accurate test equipment with current calibration and traceability.

WARNING

Some procedures require the use of high voltage. Take care to prevent contact with high potential circuits which could cause electrical shock resulting in injury or death.

5.7.1 Volts Verification

1. Place the instrument in zero check, channel A, volts and manual ranging.
2. Set the Model 619 to the 200mV range and apply +190.00mV to the channel A input. Zero correct the instrument and verify a display reading of 0.00 −3 to within ±1 count.
3. Disable zero check and verify a display reading of +190.00 −3 to within ±5 counts.
4. Repeat steps 1 through 3 using negative voltage.
5. Refer to Table 5-1 and repeat the above procedures for the remaining voltage ranges.
6. If an electrometer module is installed in channel B, repeat steps 1 through 5 for that channel.

Table 5-1. Volts Verification Limits

Range	Applied Input	Allowable Readings (18°C to 28°C)*
200mV	190.00mV	189.95 to 190.05mV
2 V	1.9000 V	1.8997 to 1.9003 V
20 V	19.000 V	18.995 to 19.005 V
200 V	190.00 V	189.95 to 190.05 V

*Does not include test equipment tolerance.

5.7.2 Amps Verification

1. Place the instrument in zero check, channel A, amps and manual ranging.
2. Set the Model 619 to the 2nA range and apply 1.9000nA to the channel A input. Zero correct the display if necessary.
3. Disable the zero check and verify a display reading of 1.9000 −9 within ±73 counts.
4. Refer to Table 5-2 and repeat the above procedures for the remaining current ranges.
5. If an electrometer module is also installed in channel B, repeat steps 1 through 4 for that channel.

NOTE

For the 200μA through 20mA ranges, for valid zero correction, input current must be no greater than 100μA. Zero correction does not apply to the 2A range.

Table 5-2. Amps Verification Limits

Range	Applied Input	Allowable Readings (18°C to 28°C)**
2 nA	1.9000 nA	1.8927 to 1.9073 nA
20 nA	19.000 nA	18.933 to 19.067 nA
200 nA	190.00 nA	189.69 to 190.31 nA
2 μA	1.9000 μA	1.8970 to 1.9030 μA
20 μA	19.000 μA	18.969 to 19.031 μA
200 μA	190.00 μA	189.70 to 190.30 μA
2mA	1.9000mA	1.8969 to 1.9031mA
20mA	19.000mA	18.970 to 19.030mA
2 A*	1.9000 A	1.8969 to 1.9031 A

*When verifying the 2A range, use the terminals designated as 2A MAX INPUT to apply the input signal.

**Limits do not include test equipment tolerance.

5.7.3 Ohms Verification

1. Place the instrument in zero check, channel A, ohms and manual ranging.
2. Set the Model 619 to 2kΩ and apply 1.9000kΩ to the input of channel A; zero correct the display if necessary.
3. Disable zero check and verify a display reading of 1.9000 +3 within ±40 counts.
4. Refer to Table 5-3 and repeat the above procedures for the remaining resistance ranges.
5. If an electrometer module is also installed in channel B, repeat steps 1 through 4 for that channel.
6. For ohms sources above 200kΩ, the resistance element should be shielded to prevent noise pickup, as shown in Figure 5-1. Note that the shield is connected to input low.
7. For resistances above 200MΩ, the test resistor should be placed in a guarded enclosure to minimize the effects of capacitance and leakage resistance. Figure 5-2 shows the basic circuit configuration using the Model 6191 Guarded Input Adapter.

WARNING

Up to 300V may be present on the guard shield. Use a safety shield connected to chassis ground to minimize possible hazards.

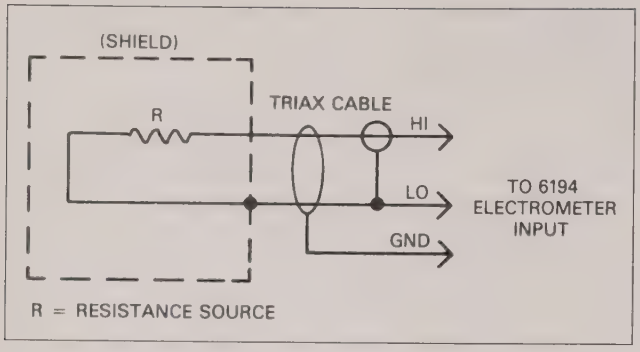


Figure 5-1. Resistance Source Shielding

Table 5-3. Ohms Verification Limits

Range	Applied Input	Allowable Readings (18°C to 28°C)*
2 kΩ	1.9000 kΩ	1.8960 to 1.9041 kΩ
20 kΩ	19.000 kΩ	18.961 to 19.039 kΩ
200 kΩ	190.00 kΩ	189.69 to 190.31 kΩ
2MΩ	1.9000MΩ	1.8970 to 1.9030MΩ
20MΩ	19.000MΩ	18.931 to 19.069MΩ
200MΩ	190.00MΩ	189.32 to 190.68MΩ
2GΩ	1.9000GΩ	1.8932 to 1.9068GΩ
20GΩ	19.000GΩ	18.809 to 19.191GΩ
200GΩ	190.00GΩ	182.40 to 197.60GΩ
2TΩ	1.5000TΩ	1.3499 to 1.6501TΩ

*Limits do not include test resistor tolerance.

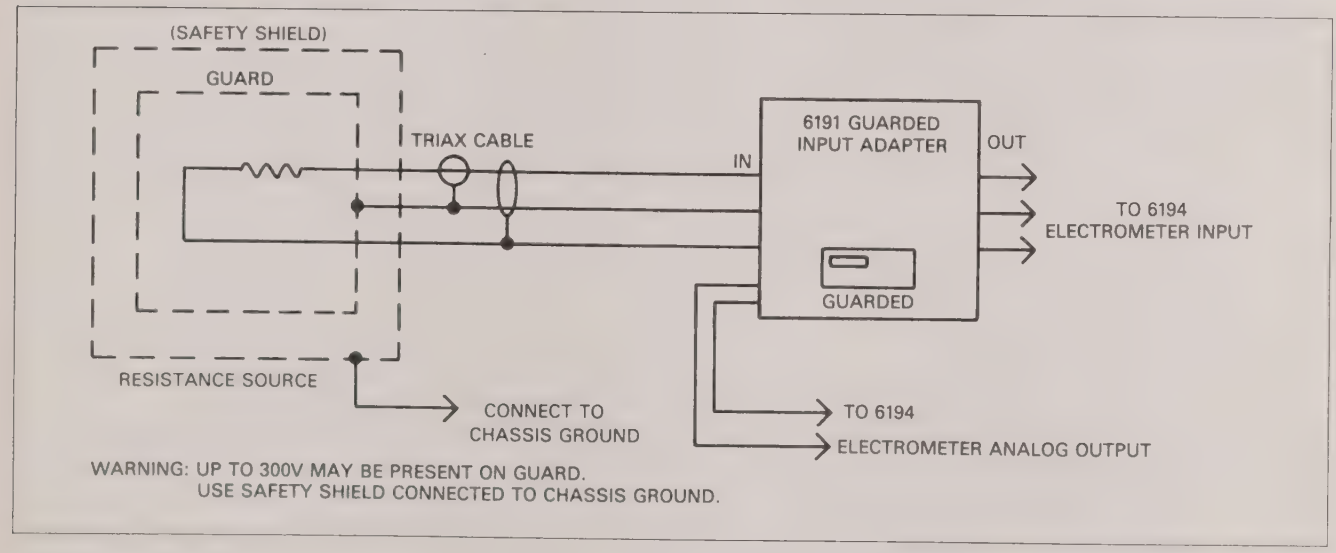


Figure 5-2. Measuring Resistance Sources Using Model 6191 Guarded Input Adapter

SECTION 6
THEORY OF OPERATION

6.1 INTRODUCTION

This section contains functional and circuit descriptions of the component parts of the Model 619 and its related modules and options. The following components are included:

- Power Supply
- Electrometer Modules
- IEEE-488 Interface Board
- Processor Board
- Display/Keyboard Board
- A/D Converter
- Filter/Multiplexer Board
- Isolator Board

The Model 619 is a versatile Electrometer/Multimeter intended for use independently or with programmed test and measurement systems. Current sensitivity and input impedance meet or exceed practical limits for most applications. Figure 6-1 provides an overall block diagram. Section 8 contains schematic diagrams to aid in understanding circuit operation.

6.2 POWER SUPPLY

For the following discussion, refer to schematic diagram 30516 in Section 8.

AC power is provided to the Model 619 by the line plug/filter, P301. Transformer 301 and the fan receive power through the series circuit of fuse F301, and switches S303 and S304. F301 and S303 are located on the rear panel of the power supply. Switch S304, mounted on the instrument front panel, is connected to the power supply through S303. The AC power is also applied to the transformer, T301, through switches S301 and S302. These switches permit transformer operation in four AC line voltage ranges. The vent fan is powered from the transformer primary through connector P302. T301 acts as an autotransformer, setting the voltage level to the fan.

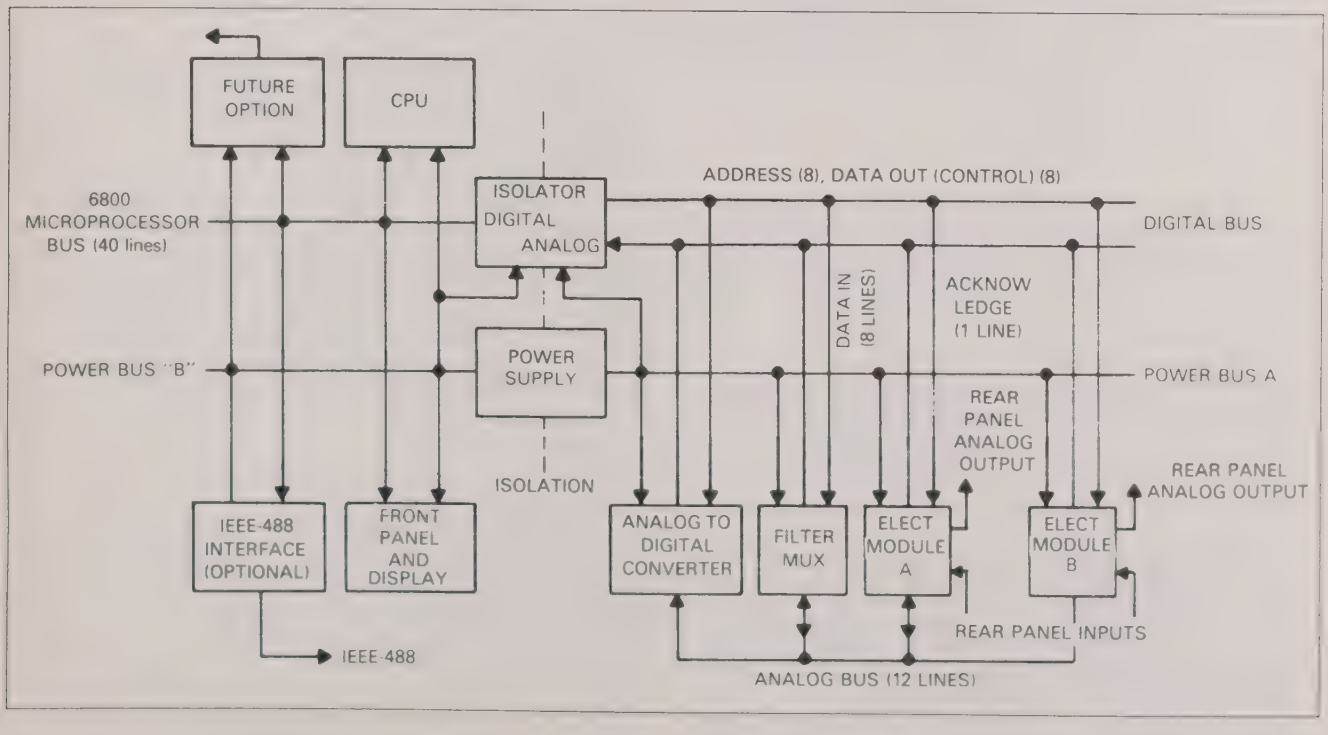


Figure 6-1. Model 619 Block Diagram

The transformer secondaries are grouped to provide power to the Model 619 digital and analog buses. The digital portion, which provides +9.5V unregulated, consists of a bridge rectifier CR301, filter capacitors C302 and C303, bleeder resistor R302, and a parallel network consisting of R301 and C301. The R301 and C301 network makes digital common electrically equal to power line (chassis) ground. The unregulated DC voltage developed is connected to the mother board digital bus J304.

The analog portion consists of bridge rectifiers CR303 and CR302, filter capacitors C304 through C312, voltage regulators VR301 through VR303 and voltage bleeder resistors R303 through R305. The AC power, 33VAC, that is used by the electrometer modules, is obtained from the winding that powers the ±15VDC rectifier, filter, and regulator portions of this circuitry. The regulated voltage potentials, of +5VDC and ±15VDC are provided to the mother board analog bus through connector J305.

6.3 MODEL 6194 ELECTROMETER MODULE

6.3.1 Description

The electrometer module is a three-function component (volts, ohms and amps). The module construction consists of two PCBs mounted together with a common rear panel. All of the module functions and ranges are programmed over the analog bus. In its various measurement configurations, the module processes an input measurement to an output of 200mV or 2V, which is further processed by the A/D converter and filter/multiplexer.

A Model 619 may contain one or two Model 6194 Electrometer Modules. When two are installed, the one on the left (as viewed from the rear) is channel A. The second Model 6194 is channel B. Figure 6-2 provides an overall view of the Electrometer Module.

The heart of the design is a bootstrapped op-amp with an ultra-low input bias current. The input overload protection is provided by a ballast and by current limiting on the bootstrapped output. This circuit can be arranged in two versions.

1. In amps the circuit is arranged as a current to voltage converter. Various feedback resistances are used to measure a wide range of input current.
2. The circuit can also be arranged as a high input impedance unity-gain buffer which is utilized for both volts and ohms measurements. When in the ohms configuration, a constant current source consisting of a bootstrapped voltage reference and various feedback resistances is used to convert an unknown resistance to a measurable voltage level.

The input to the module is via a triax connector. Separate binding posts and a microphone connector are provided for the 2A current range and analog output respectively. All input/output connections, along with a fuse, are located on the rear panel of the module. A calibrated resistive divider couples the module output to the input of an A/D converter at 200mV and 2V.

Power is supplied to the module via a transformer isolated, floating power supply. The logic for decoding and latching system commands to the electrometer modules are shown in the block diagram in Figure 6-2.

6.3.2 Circuit Operation

For the following description, refer to schematic diagrams 30522 and 30523, located in Section 8.

The power and control inputs are obtained by plugging the module P-C edge connectors into the appropriate connectors on the Model 619 mother board. This connector ties the module to the analog bus. Tables 6-5 and 6-6 are the pin assignments for channel A and B electrometers respectively. The input module identity is wired into the mother board by transposing address lines A0 and A1 between channels A and B locations on the mother board.

The electrometer module, schematic diagram 30522, contains the module power supply, output circuitry and 2A current range shunt. The power supply option of the circuitry provides three basic voltage levels for the module. It provides ±260VDC (TP-1 and TP-2 to input common) which is used by the output circuitry when configured in the volts or ohms functions. It also provides ±8VDC (TP-3 and TP-4 to TP-6) for use by the output circuitry when configured in the amps function. This also eliminates the necessity of the ±260V supply having to supply greater than 2mA. The ±17VDC (TP-7 and TP-8 to TP-9) bootstrapped supply is used by the input amplifier and ohms reference on schematic diagram 30523. The transformer (T601) in addition to providing the various voltage levels, serves to isolate the module from other instrument voltage sources.

The center of the output circuitry is a bipolar totem pole arrangement consisting of high voltage transistors Q601, Q603, Q604 and Q602. Resistors R601, R606, R608 and R602 bias their respective transistors to ensure that the voltage burden is equally divided between the two transistors at each end of the network. The network is current biased by the voltage developed across CR615 through CR618. CR615 through CR618 are essentially connected across the totem pole arrangement. In the amps function, the contacts B and C of relay K602 short out R615 and R167. This action increases the

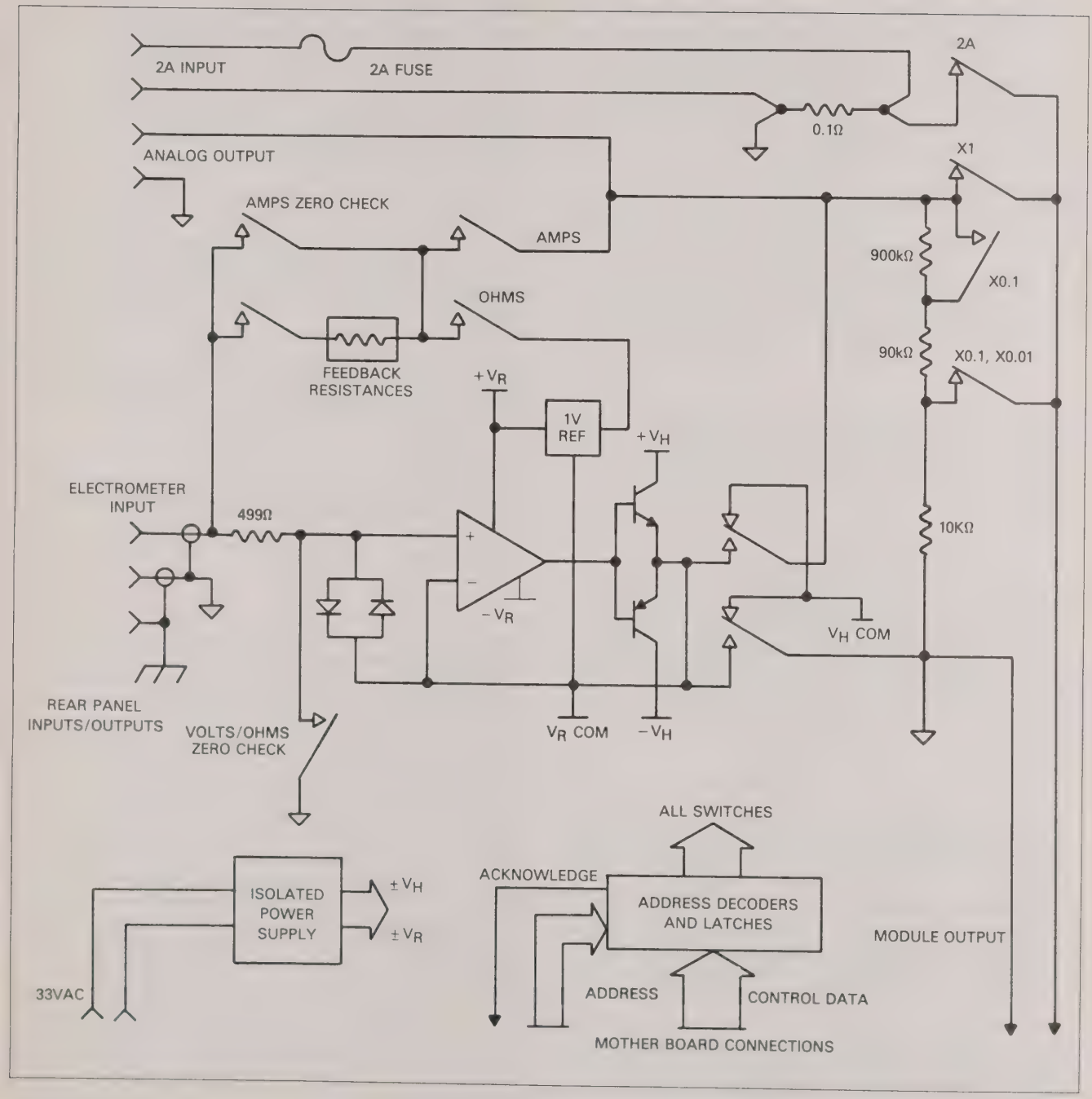


Figure 6-2. Electrometer Module Block Diagram

bias current level. The bipolar networks consisting of Q605, Q606, CR620, CR619, R613 and R615, limit the output current ranges. The top ends of the high voltage "totem pole," which are disconnected by contacts A and B relay K601, prevent excessive power from getting to this particular portion of the circuitry. In this mode, input is supplied to Q603 and Q604 through CR605 and CR608. Capacitor C605 serves as response stabilization in the amps configuration. CR605 through CR608 have an additional function in disconnecting the ±8VDC supply (TP-3 and TP-4 to TP-6) from the circuit when it is in the volts or ohms functions. CR602 and CR604 disconnect the entire output circuit from the ±260VDC supply during input voltage overload either volts or ohms. The drive to the output circuit is provided by the bootstrapped amplifier U651 on the electrometer module, schematic diagram 30523, and via Pin 56 on the intramodule bus.

R607, R609, CR613 and CR614 provide extra drive current to Q601 and Q602 when the circuit is operating near the ±260V supply voltage level. CR601 and CR603 protect the emitter-base junctions of transistors Q601 and Q602 from reverse voltage bias.

Controlling the configuration of the output circuitry are the relays K601 and K602. These two relays are actuated by R611, R610, Q607 and Q608 along with commutation diodes CR623 and CR622. Control is provided via Pin 52 on the intramodule bus from logic decoders on the electrometer module, schematic diagram 30523. K601 sets up the output for both volts and ohms functions providing for a non-inverting gain. K602 sets up the output for the amps function by providing for an inverting gain conversion.

The remaining circuitry on schematic diagram 30522 includes the 2A current range shunt resistance, R605. The 2A range has separate binding post inputs, J601 and J602, and fuse protection F601. Relay K603 along with commutation diode CR621 selects this range for connection to the module output. Control is provided from logic decoders on schematic diagram 30523 via Pin 52 on the intramodule bus. Fuse F601 provides overload protection and is mounted for access on the rear panel of the module.

The rest of the electrometer module circuitry is located on schematic diagram 30523 circuitry includes the following:

- Input Amplifier
- Feedback Networks
- Ohms Reference
- Bootstrapped Power Supply Regulators
- Module Output Attenuator
- Control Logic Decoders

The input amplifier consists of a group of components: R664, R665, R667, R668, R669, R656, C651, C658, C661, K656 and U651. The heart of this section of the circuit is the electrometer operational amplifier, U651. Providing the active forward gain portion of the electrometer module, this circuitry is combined with the feedback networks and bootstrapped ohms voltage reference to provide amps and ohms along with the basic volts measurements.

Potentiometer R656 is used to trim the input offset voltage for U651 while R667 and C661 provide a pole/zero stabilization to this forward gain block of the module. R669 is the pull-up resistor for the output circuitry on schematic diagram 30522. R668 provides the input protection for U651 by limiting the input current. C658 (along with R668) provides input stabilization on volts and ohms functions. Relay K656 is the zero check contact with R665 limiting the zero check input current. R664 and C651 provide compensation for this extra input resistance in the amps function.

Five feedback networks are used in setting up the electrometer module for both the amps and ohms functions. Utilizing the inverting mode of the module output circuitry a current-to-voltage converter is obtained.

A bootstrapped voltage reference develops a constant current source for use with the non-inverting module output circuitry mode, for ohms measurements. The five networks used are 100Ω (R601, R607), 10kΩ (R659, R652), 1MΩ (R660, R653), 100MΩ (R662, R654) and 10GΩ (R663, R655, R666). Potentiometers R651 through R655 permit calibration of five networks. Capacitors C652, C653, C656 and C657 stabilize the feedback response. Resistors R661 and R688 protect relay contact K657 from momentary current surges when capacitors C653 and C656 are connected together. Connection of the proper feedback network into the circuit is made by high isolation impedance relays K651 through K654 and normal isolation impedance relay K657. High isolation impedance relay K655 provides a low resistance feedback network which is used for amps zero check. Connections to the input by relay K655 is made after R665, to limit the effect of the relay contact resistance on the measured zero offset.

The ohms voltage reference consists of K658, K659, VR653, U653, R676, R675, R672, R673, R670, R657 and C662. The voltage reference is obtained from VR652; scaled by R670, R672 and R673; and calibrated by R657. Op amp U653 buffers the scaled voltage across R670 providing a low output impedance to the feedback networks. C662 and R675 serve to frequency compensate U653. R676 limits the overload current on the output of U653. When VR653 is switched in by relay K659, it limits the voltage across the resistance being measured. The connection of the ohms reference to the feedback networks is made via relay K658.

Power to ohms reference and the input amplifier is provided by the power supply circuitry which consits of U652, VR651, VR652, R674, R677, R671, C654, C659 and C660. These bipolar voltage supplies are bootstrapped to the electrometer module output in the volts and ohms configurations. The negative voltage (−VR) is provided by regulator VR651. Positive voltage (+VR) is provided by U652 which amplifies the reference zener (VR652) voltage. Capacitors C654, C659 and C660 provide the transient response protection.

The parallel combination of R687 and C665 serves to limit output current from U651 preventing excessive current draw from U652 and subsequent latch up of the input circuitry.

The module output attenuator provides a 2V full scale output to the A/D converter for those ranges and functions which result in a 20V or 200V full scale analog output. This portion of the circuitry consists of R679 through R683 and relays K660 through K662. As mentioned previously, the A/D converter has two ranges of operation, 2V and 200mV full scale. Potentiometers R679 and R680 calibrate the two attenuation gains of 0.1 and 0.01. Relays K660 through K662 select either the unscaled module output (K661) or the output attenuator (K662) X0.01 or X0.1 (K660).

Resistors R686 and R678 are included to protect the electrometer module circuitry. Resistor R678 protects the module from imposing a voltage potential from analog output (J652) common to module input (J651) common. Resistor R686 protects the module from transient voltage input from the module output connection in the analog bus.

The remaining portion of the Model 6194 Electrometer circuitry is the control logic decoder. This portion of the module consists of U654 through U658, Q651, R685, C664 and commutation diodes CR652 through CR663 and CR664. U654 and U655 are octal D-type transparent latches which store the appropriate data from control data inputs and drive the module configuration relays. Data is clocked in by decoding the module address through U656A and B. Controlling the module requires "Function Byte" (U654) and a "Range Byte" (U655) which are latched with the appropriate address. These addresses and function/range bytes are listed in Table 6-7. The identification or control performed by each data bit in the function/range bytes is listed in Table 6-8.

An acknowledge circuit, which consists of U656, R684 and Q651, provides output to a wired NOR control line on the "Analog Bus". This serves to acknowledge the receipt of a proper address by the module.

The section of circuitry consisting of U657C and D, R685, CR664 and C664 performs a power up disable function. The output of both latches U654 and U655 will be disabled upon power up until receipt of a proper module function-byte address. This prevents a random (and erroneous) configuration of the electrometer module by power up transients. Additional logic prevents erroneous, simultaneous actuation of relays which could result in damage to the module.

Capacitors C666 through C668 prevent noise pickup and subsequent erroneous relay actuation.

6.4 MODEL 6193 IEEE-488 INTERFACE BOARD

6.4.1 Description

The IEEE-488 interface board utilizes the Motorola 68488 IEEE IC which is capable of performing all IEEE talker/listener protocols. The board was designed to be an interrupt driven I/O device. The board contains Motorola 3448A IEEE bus transceivers, which are capable of driving and terminating the IEEE bus per the IEEE-488 specifications.

A rear-panel accessible address switch is on the board for choosing an IEEE talker/listener pair address for the Model 619. The IEEE connector is on the rear panel. The five-bit interface address is back-panel selectable. The address switches are preset, prior to shipment, to primary address of binary 6 (00110).

6.4.2 Circuit Operation

When reading the theory of operation for the IEEE interface board, refer to schematic diagram 30518 for reference designations.

The Model 6193 IEEE interface is built around the Motorola 68488 IEEE LSI device U706. The 68488 is a Motorola 6800 family peripheral IC.

The PCB is buffered on data, address and control lines to present only a one bus load. U703 buffers all of the address and control lines. BA0-BA2 make up the RS0-RS2 register selects on the 68488. The 68488 has 16 registers of which eight are read only and eight are write only. The use of the R/W (read/write) line allows access to the eight register banks. See Table 6-1 for register commands.

Table 6-1. Register Commands

RS2	RS1	RS0	R/W	Register Title	Symbol
0	0	0	1	Interrupt Status	ROR
0	0	0	0	Interrupt Mask	ROW
0	0	1	1	Command Status	R1R
0	0	1	0	Not Used	—
0	1	0	1	Address Status	R2R
0	1	0	0	Address Mode	R2W
0	1	1	1	Auxiliary Command	R3R
0	1	1	0	Auxiliary Command	R3W
1	0	0	1	Address Switch	R4R
1	0	0	0	Address	R4W
1	0	1	1	Serial Poll	R5R
1	0	1	0	Serial Poll	R5W
1	1	0	1	Command Pass-Through	R6R
1	1	0	0	Parallel Poll	R6W
1	1	1	1	Data In	R7R
1	1	1	0	Data Out	R7W

U707A and U708A decode A11, A12 and IOEN to form $\overline{\text{BDSEL}}$ (Board Select) (TP1). The BDSEL decoding will place the PCB at memory space address 9000_H-$97FF_H$. This allows 2k of address space for the 68488 of which the first 16 bytes are used. U707B inverts $\overline{\text{BDSEL}}$ to form BDSEL. U708B decodes BDSEL, E and R/W to $\overline{\text{DRVENB}}$ (Drive Enable) (TP2) which when high allows the inverting tri-state data buffers U711 and U710 to drive the data bus.

U707C inverts the R/W signal to form $\overline{\text{R/W}}$. U708C decodes $\overline{\text{R/W}}$, BDSEL and E to form $\overline{\text{REC ENB}}$ (Recive Enable) (TP3) which when low allows the inverting tri-state data buffers U711 and U710 to receive from the data bus.

The E signal (System Φ2) is used in the decoding of U708B and U708C to turn the buffers OFF when they are not driving/sending, thereby lowering their power consumption.

In the 68488 one of the 16 registers R4R is not present on board the chip itself. When the chip decodes this register, it generates $\overline{\text{ASE}}$ which is used to enable an extra register U709 onto the data bus. U709 is a tri-state buffer which is tri-stated when $\overline{\text{ASE}}$ is high and drives the data lines when $\overline{\text{ASE}}$ is low. The information on U709's input is provided by address switch S701. S701 is located on the rear panel of the IEEE-488 interface board. The necessary pull up resistors for the switch bank are provided by the thick film resistor network R701. The processor reads these switches and then knows which talker and listener address to assign to the 68488 chip, and thereby access the instrument.

U702 and U705 are the data bus buffers for the IEEE bus. U704 and U701 are the handshake and control buffers for the IEEE bus. The buffers consist of four independent driver/receiver pairs with bus termination resistors on board. They also have the capability of either tri-state or open collector operation depending on the bus requirement. The Model 6193 is designed to use them in the open collector configuration. U707E, T/R2 and T/R1 form the control for the bus buffers U701, U704, U705 and U702.

U702 and U705 data bus buffers are fully bi-directional as indicated by the arrows on the schematic 30518. U701 Pins 3, 5 and 13 (which are NRFD, NDAC and DAV respectively) are also fully bi-directional. U704 Pin 11 (EOI) is fully bi-directional. U707 Pin 11 (ATN) and U704 Pins 3 and 13 (REN and IFC respectively) are receive only and U704 Pin 5 (SRQ) is send only. A typical section is shown in Figure 6-3.

VR701 supplies the +5V ±5% regulated power needed by the PCB.

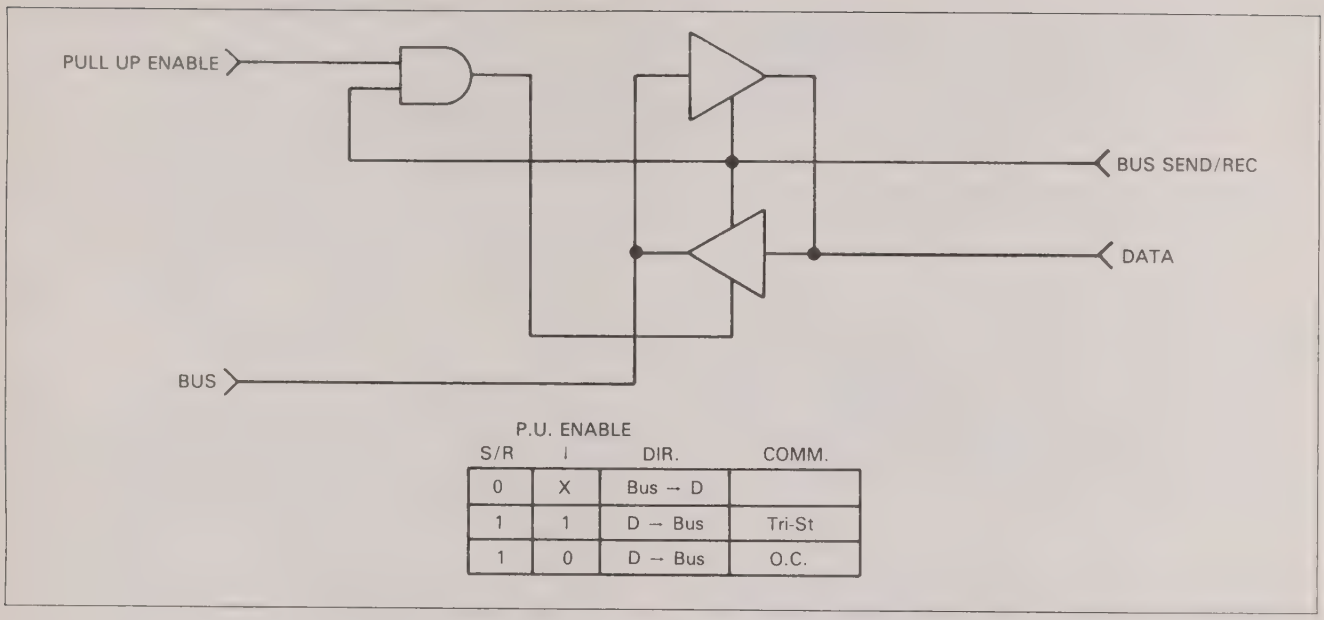
6.5 PROCESSOR (CPU) BOARD

6.5.1 Description

The CPU board has a circuit which resets the processor upon power up to ensure proper system operation. This circuit can also be controlled via the watchdog line from one of the interval timers in case of program malfunction. This function will be discussed in more detail later in this section. The CPU has provisions for 8k words of ROM (or EPROM) program memory on board with decoding for an additional 8k ROM external. It also has provisions for up to 2k RAM scratch-pad memory board. With the 6840 LSI chip, the CPU can have three hardware interval timers. It can support both interrupt and DMA driver I/O systems. A 4MHz crystal oscillator is used to provide all timing for the 6808 CPU chip and digital system components. A partially decoded I/O enable line (IOEN) is provided for use by system I/O components to ease their memory space decoding. The board is capable of supporting signature analysis troubleshooting techniques.

6.5.2 Circuit Description

When reading through the theory of operation for the CPU board, refer to schematic diagram 30519 for reference designations.



P.U. ENABLE

S/R	I	DIR.	COMM.
0	X	Bus → D	
1	1	D → Bus	Tri-St
1	0	D → Bus	O.C.

Figure 6-3. Data Bus Buffer

The Model 619 Electrometer/Multimeter control processor unit (CPU) is constructed around the Motorola 6808 microprocessor (U905). This particular processor is a Motorola 6800 series processor with an internal clock.

The Motorola 6808 LSI microprocessor requires a 20msec reset pulse when power is turned on to get its dynamic buffers and the clock running properly. This reset delay is provided by timer U917. The output of U917 is inverted by U916D and applied to the reset pin of the microprocessor (Pin 40). It also goes to all other devices in the system which require power up resets via bus Pin 28 (i.e., PIA's, VIA's, etc.).

U913 is a Motorola 6840 timer peripheral. It is part of the Motorola 6800 series family of parts. The 6840 contains three fully programmable hardware timers with interrupt and output capability. U916C is controlled by the 6840 (U913) software controllable timer 1, which monitors the running software. U913 timer 3 is used to establish real timer interrupts to the running software. U913 timer 2 outputs a 120Hz signal on Pin 3 (TP12) to allow oscilloscope monitoring for determining whether the IC is functional. U913 is an I/O device to the system, U902B decodes BA9, BA10, BA11 and BA12 to form one chip select for U913. The other chip select for U913 is provided by BIOEN which will be discussed later in this section. The memory space is $9E00_H$-$9FFF_H$, of which eight locations are used by the chip. Placing U913 in the I/O configuration gives it added flexibility in that it can be used by DMA (Direct Memory Access) devices or other I/O components if needed. See Table 6-2 for register commands.

Table 6-2. Register Commands

RS2	RS1	RS0	R/W5=0	R/W=1
0	0	0	CR2=0 Write #3 CR1=1 Write #3	NOP NOP
0	0	1	Write Control Register #1	Read Status Register
0	1	0	Write MSB Register	Read Timer #1 Counter
0	1	1	Write Timer #1 Latch	Read LSB Register
1	0	0	Write MSB Register	Read Timer #2 Counter
1	0	1	Write Timer #2 Latch	Read LSB Register
1	1	0	Write MSB Register	Read Timer #3 Counter
1	1	1	Writer Timer #3 Latch	Read LSB Register

The 6808 microprocessor data bus D0-D7 is buffered and inverted by U921 and U918 to form $\overline{BD0}$-$\overline{BD7}$ and is provided to the system. The unbuffered data bus is routed to all the memory devices on the PC board. The control for data transfer into the CPU is derived by U903B (TP7). It decodes Φ2, A15, A13 and R/$\overline{W}$ to form the $\overline{RECENB}$ (Receive Enable) signal. The $\overline{RECENB}$ signal allows the buffer to receive from

the data bus. The control for data transfer into the CPU is derived by U904C (TP6). It decodes R/W, BA, BΦ02 to form the DRVENB (Drive Enable) signal. The DRVENB singal allows the buffer to drive the data bus.

Decoded Φ2 is used for all of the buffers in order to make them tri-state for reduction in power consumption.

The 6808 address bus A0-A15 is buffered by U908 and U901 to form BA0-BA15 which is provided to the system. To aid I/O device decoding in the system BA13, BA14, BA15 and BVUA are decoded by U909C, B, A and U902A to form the IOEN (I/O Enable) signal. This signal is buffered by U911 to form BIOEN. In addition to IOEN, U911 does all the control line buffering; it buffers I, R/W, VMA (to form BVUA) and BBA/DMAGNT (Direct Memory Access Grant) for use by the Model 619 system.

All on board ROM memory decoding is done by U914A, U903A, U904A, U912 and U910B. U903A and U904A form the ROME (ROM Enable) signal. This enables U914A, the 2 or 4 decoder to select the appropriate device based on A11 (Pin 2) and A12 (Pin 3) of U914. The 6808 requires vectors from memory to branch to various sections of software. These vectors must appear in locations $FFF8_H$-$FFFF_H$ in the memory space.

The Vector JAM signal allows the top block of ROM to be double addressed for this purpose. The top block responds to $FFF8_H$-$FFFF_H$ as well as its normal address. U912D and U912C perform the necessary "OR"ing function. Therefore, $\overline{DSEL4}$ (TP4) decodes memory spaces $B800_H$-$BFFFF_H$ and $E000_H$-$FFFF_H$. Signal $\overline{DSEL1}$ (TP3) decodes $A800_H$-F_H memory space, ROM U924. Signal $\overline{DSEL2}$ (TP2) decodes $A800_H$-$AFFF_H$ memory space, ROM U915. Signal $\overline{DSEL3}$ (TP1) decodes $B000_H$-$B7FF_H$ memory space, ROM U907. The above process is used for 2716 memory devices. Refer to Table 6-3 for selection of PROMS. $\overline{DSEL3}$ selects $A000_H$-$AFFF_H$ memory space, ROM U907, and $\overline{DSEL4}$ selects $B000_H$-$BFFF_H$ memory space, ROM U906, as there is only 8k maximum of ROM allowed. Memory space $C000_H$-$DFFF_H$ is reserved for external ROM. See Figure 6-4 for memory space map.

NOTE

The subscript H, as in $E000_H$, denotes a hexadecimal location in memory or hex notation of a number.

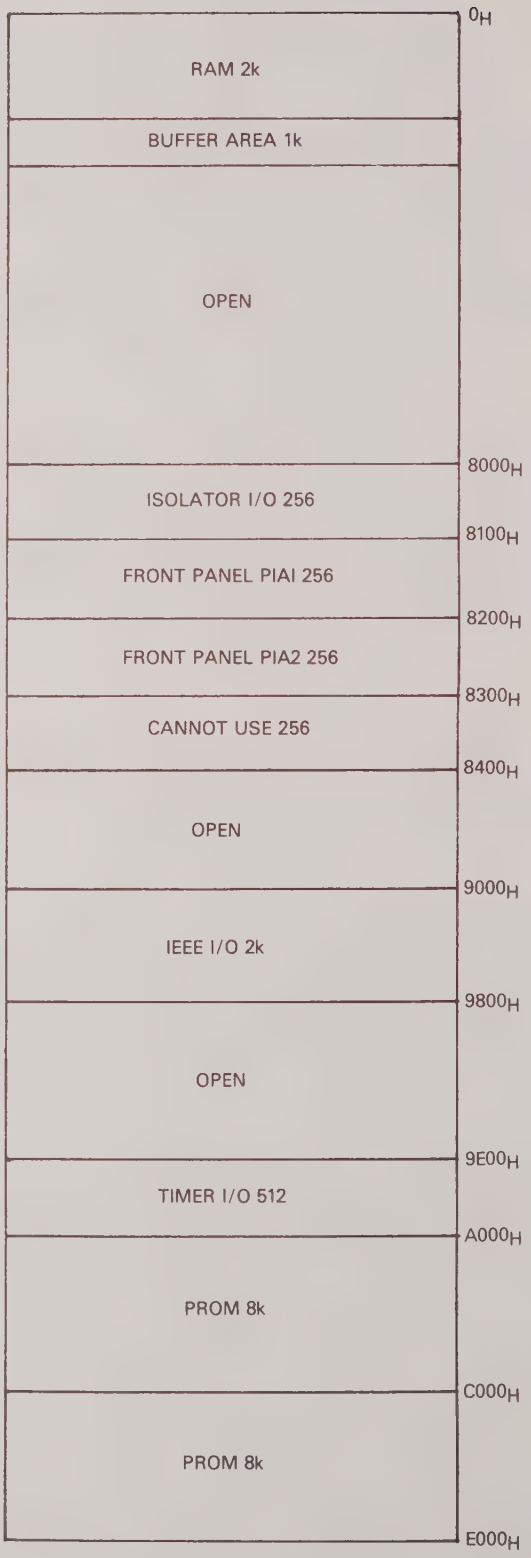


Figure 6-4. Memory Map

Table 6-3. Jumpers for PROM Selection

Configuration	W901	W902	W903	W904	W905	W906	W907	W908	W909
2716 PROMS (2k)	O	X	X	O	*	X	X	X	
2732 PROMS (4k)	*	X	x	*	O	X	X	X	O

X = Don't Care
* = In
O = Out

All of the on board RAM decoding is done by U904B and U914B. U904B decodes A14, A15 and Φ2 to form RAME (RAM Enable) which enables U914B the 2 of 4 decoder. When A13 is low, depending on the state of A10 (Pin 14), either $\overline{SRAM1}$ (Select lower 1k) memory space 0000_H-$03FF_H$ or $\overline{SRAM2}$ (Select upper 1k) memory space 0400_H-$07FF_H$ is generated to select the appropriate RAM bank. The RAM chips are 1k by 4k (2114) memory devices; thus two chips in each bank are necessary for the required 8 bits of data. U919 and U920 are the low order 4 bits and U922 and U923 are the high order 4 bits. The other signal needed by the RAM's is the $\overline{WE}$ (Write Enable) signal. This signal is generated by U910C and U909F which decodes R/W, Φ2 and VMA.

The 5VDC regulated to ±5% is provided by VR901 and associated capacitors. Crystal Y901 and capacitors C910 and C911 form the 4MHz oscillator clock needed by the 6808 IC. The 6808 divides this frequency by 4 and provides a 1MHz output (Pin 37) E clock for system synchronization.

6.6 ISOLATOR BOARD

6.6.1 Description

The isolator board interfaces digital bus A to analog bus B. Four optical isolators are utilized for signal coupling without impedance coupling. Data, control and address information is transmitted (with odd parity) to the analog side of the isolator, using three of the optical isolators. At the same time data from the A/D is transmitted to the digital side of the isolator board across the fourth optical isolator.

The isolator board also provides address decoding and power for the display board as well as buffering for all lines going to the display board from the digital bus.

6.6.2 Circuit Operation

Refer to Schematic Diagram 30520 for the following discussion.

The isolator board is designed around the Syntertek 6522 Versatile Interface Adapter (U807).

The board is buffered on data, control, and address lines to present one bus load to the Model 619 bus. U805 and U806 buffer the data lines. U803 buffers the control and address lines. U801E, F and U804A decode BA12, BA11 and BIOEN respectively to form BDSEL (Board Select) signal. There is no buffering on lines BA12, BA11 and BIOEN as well as BA8, BA9 and BA10 since they only represent one load to the bus. U801A inverts BDSEL to form BDSEL. There is also one chip select for U807. BDSEL is also inverted by U801B to form one chip select for the display board PIA's.

U802A decodes BA8, BA9 and BA10 to form other chip selects for the interface. U802A Pin 4 seletcs U807. This decoding arrangement places U807 in memory space 8000-80FF allowing 256 memory locations; however, only 16 are used. U802A Pin 5 form S1 which selects U204 on the display board. This arrangement provides 256 memory locations of which only four are used.

U802A Pin 6 forms S2, which selects U207 on the display board. This provides 256 memory locations of which only four are used. U802A Pin 7 is not used. All of the additional signal control lines needed by the display board, E, A6, A7 and R/W, are buffered by U803. The Data lines D0-D7 are buffered by U805 and U806. Reset and +5VDC and ground (B com) are not buffered. All of these lines go to the display board through connector 801.

U804C and U801C decode R/W, E and BDSEL to form DRVENB (Drive Enable) (TP1) in order to gate the data buffers and to send data to the data bus.

U801D and U804B decode R/W, E and BDSEL to form RECENB (Receive Enable) (TP2) in order to gate the data buffers for receiving from the data bus.

The heart of the isolator board is the 6522 Versatile Interface Adapter (VIA) a fully programmable I/O device. The VIA internally consists of 2 software programmable timers, two programmable bi-directional 8-bit parallel I/O ports (similar to PIA's) and a serial communication port. The device contains control registers which are programmable in determining which of the many modes of operation are to be utilized. Lines CB1 and CB2 form the serial communications port and PA0-PA7 (Port A) and PB0-PB7 (Port B) form the bi-directional parallel I/O ports. Internal register bits are shown in Table 6-4.

Table 6-4. Register Commands

RS3	RS2	RS1	RS0	Register	Comments
0	0	0	0	ORB, IRB	Effect Handshake
0	0	0	1	ORA, IRA	Effect Handshake
0	0	1	0	DDRB	Data Direction B
0	0	1	1	DDRA	Data Direction A
0	1	0	0	T1	Timer 1
0	1	0	1	T1	Timer 1
0	1	1	0	T1	Timer 1
0	1	1	1	T1	Timer 1
1	0	0	0	T2	Timer 2
1	0	0	1	T2	Timer 2
1	0	1	0	SR	Serial Port Data
1	0	1	1	ACR	Control Register
1	1	0	0	PCR	Peripheral Control
1	1	0	1	IFR	IRQ Mask
1	1	1	0	IEB	IRQ Enable
1	1	1	1	ORA	No-Effect Handshake

For the serial I/O, the clock is programmed for a 500kHz shift rate. The parallel I/O Port A lines PA0-PA7 are programmed as inputs and Port B lines PB3-PB7 are also programmed as inputs. Port B lines and PB0 are programmed as outputs.

The actual operation is as follows: A byte of data is written via the software into the 6522 (VIA) serial out register. The LSI device forms the clock and data for the serial bit streams on CB1 and CB2. The clock bit streams goes through U809A and opto isolator AT3 and U810A to be the shift clock for U812, U815 serial to parallel converters, and U816 parallel to serial converter on the isolated side. U809A Pin 14 is a clock enable which is utilized to disable the clock if the need arises. U809A also provides the drive needed by the opto isolator AT3. The data bit stream goes through opto isolator AT3 and U810A to be the data for shift register U812 and U815. U809B provides the drive for the opto isolator AT2. U811 and U814 are generator parity/checker devices.

When the shifting is completed and U811 Pin 5 goes low, this indicates odd parity. During the shifting operation, this line goes low many times depending on the state if the shift registers. Therefore, U810B Pin 9 is an enable line, so that when the data has been sent, the software causes an enable low after shift. On the analog/digital bus this is used as an address latch enable signal to latch in the address of the analog device to which data is being sent. The data to be written is placed on the outputs of U815 and the address is placed on the outputs of U812. The software then sends PB2, which disables the address latch enable, making the enable line go high. At the same time U810D Pin 4 (latch line) goes low, this causes the ACK line path to be selected and ACK (Acknowledge) will be sent back from the analog side. If the receiving analog device has latched in its address, it responds via the ACK line. This is inverted by U813A and goes to opto isolator AT4 and then to U807, CA1 and PB7. CA1 interrupts the system when the ACK line becomes true. Polling can be done to sense a change on PB7. U813C provides the drive needed by the opto isolator AT4. There are 2 types of error checking in transit. A parity check followed by an ACK handshake completion. Upon error, retransmission of data can be requested via the software.

To receive data from the analog side, U807 PB2 is set to disable the ACK path and enable the data path via U813D Pin 12. The data shifts out at clock CB1 rate from U816 going through U813C, and opto isolator AT4 into serial parallel converter U808. It is then presented to U807 Port A. The software can then read the 8-bit data. On receive U816 recirculates the data presented to it by the analog side. Thus, multiple reads and compares may be done via software to enable error checking for receive data. Upon error, retransmission of data can be requested via the software.

For test purposes, jumper J1 is provided to allow the isolator to recirculate data or talk to itself (provided U815 Pin 13 is not being interrupted by the analog bus).

Jumper J2 allows for odd parity checking, or no parity checking depending on the system needs.

The regulated 5V ±5% is provided to the isolator digital side by VR801 and associated capacitors.

6.7 DISPLAY/KEYBOARD

6.7.1 Description

The display/keyboard has three main areas, the keyboard, annunciators and numeric displays. The keyboard area consists of a four by six matrix for a total of 24 switch locations. Sixteen of these switches are used in the Model 619 to select range, function and channel. The annunciator area consists of 23 LED's. The Model 619 uses 21 annunciators to display the status of the instrument. The display area consists of a signed 5½ digit mantissa and a signed 2-digit exponent.

All the display board hardware decoding is done on the isolator PCB. The decoding places the PCB at memory address 8100_H-$82FF_H$. U204 is located at 8100_H-$81FF_H$ and U207 is located at 8200_H-$82FF_H$. The power for the display board is also derived from the isolator board. All signal and power lines are delivered to the display PCB via the connector cable.

6.7.2 Circuit Operation

Refer to schematic diagram 30515 for the following discussion.

The heart of the display board consists of U204 and U207 Motorola 6800 family peripheral interface adapter chips (PIA's) which are fully software programmable.

The PIA's internally consist of two programmable control registers which determine which of many modes of operation are to be used. The PIA's also contain two programmable data direction registers, which are also data I/O registers if bit 2 in the corresponding control register is set to 1. Both control registers are initialized to 3C. This configures the PIA's for non-interrupt operation standard mode.

Data direction is configured for U204 by Port A outputs and Port B outputs, and for U207 by Port A inputs and Port B outputs.

U204 I/O Port B is the common cathode control strobe used to turn the display on. Each of the eight lines turns on one bank of LED's plus one display digit. U207 I/O Port B is the segment select control to select appropriate segments of the display digits U204 I/O Port A lines. PA0, PA1 and PA2 are the LED select controls to select the appropriate LED in the LED bank. U204 I/O Port A line PA3 is used to key the beeper on and off; U204 Port A lines PA4-PA7 form the column lines to the switch matrix and U207 Port A lines form the row lines to the switch matrix. U204 Port A lines PA4-PA7 are used to enable the appropriate switch column for the software switch scan. U207 Port A is used to read the scanned switch bank to determine which switch has been depressed. Switch debounce, N key rollover, and switch validation are all done in software.

U201, U203 and U205 are buffers to drive the displays, LED's and switches.

6.8 A/D BOARD

6.8.1 Description

The A/D board consists of the basic hybrid charge balance dual slope A/D. There are no references or multiplexed inputs. The control of this board is from the CPU board through the digital isolator board.

The input voltage is converted into a current in the GAMP (Transconductance Amplifier). When the output of the integrator ramps up to the threshold of the "D" flip-flop, the 2mA current source is turned on until the output of the integrator ramps down below the threshold of the "D" flip-flop. The number of pulses produced is accumulated in the event counter.

Upon completion of signal integrate, and based on the length of time determined by the number loaded into the integration time counter, the number in the event counter is multiplexed into the processor. The event counter is cleared and the single slope current source is switched on. The time required to ramp to zero is measured by counting the clock in the event counter. This number is also multiplexed into the processor. From these two numbers the total number of counts can be calculated.

6.8.2 Circuit Operation

When reading through the theory of operation for the A/D board, refer to schematic diagrm 30521.

The Transconductance Amplifier (GAMP) performs two functions:

1. Converts the input signal voltage to a current for the integrator.
2. It provides an offset to make the A/D bipolar. That is a plus and minus voltage for input to the A/D.

The op amp reference is biased at approximately −2.5V or minus full scale by VR501 as a negative reference, and by resistors R501 (25k) and KR501 (39k). Resistor R501 (3.9k) forms a current source due to the constant voltage across it. It is equal to the voltage across R501 (39k) due to the feedback action of the op amp.

Ib is set to approximately the value of Vin max/Rin.

Then:
Vin = Vmax, I=0
Vin = 0, I=Ib
Vin = Vmax, I=2Ib

The charge balancing consists of an integrator, a positive current source with a current switch, and the negative signal current.

When U513 Pin 1 (signal integrate) goes low, Isig (signal current) flows out of the summing junction and ramps up to the threshold of the "D" flip-flop, therefore, the current Icb (charge balancing current) is turned on for one clock period. Icb is slightly greater than Isig full scale.

The value of C502 which is the integrator capacitor prevents the output of the integrator from ranging below ground or above +5V.

U513A enables charge balance pulses only during signal integrate. Q503 prevents current limiting in the output of U507 op amp and clamps the output of the integrator to ±5V to protect the "D" flip-flop. U507 is a FET input op amp that prevents any extra currents from flowing out of the summing junction during the instantaneous overloads as the charge balance pulses or signal current are switched off and on.

R503 is a linearity resistor. The nonlinearity in the A/D is a square law curve. The amount of current removed from the summing junction by this resistor is proportional to the voltage across the diode junction to the summing junction in U507. This induces a compensating logarithmic nonlinearity. The basic nonlinearity is only 10 to 50ppm. The compensation corrects this error to 1 to 10ppm.

The residual charge on the capacitor is ramped down to zero volts by the start single slope control signal. The single slope current is 1/128 of the charge balance current. This ratio is between R501 (320k) and R501 (2.44k) taking into account that base emitter voltage drops of Q505, Q506 and Q507. However, the charge balance is on only 50% of the time, so the effective ratio is 1/256 (Refer to Event Counter Operation). During operation, the last digit displayed is approximately the single slope contribution, so this ratio only has to be accurate to 1% to 10%.

The IMC1 line has 10V on it and is a byproduct of the reference circuit in the filter/mux board.

The clock is composed of an oscillator and a divider circuit. The oscillator is a classic Pierce oscillator circuit developing 4.915MHz. U516 (74193) divides the oscillator frequency to 307.2kHz and 614.4kHz. The 307.2kHz after being buffered by U508A is divided down even further to 1200Hz by U505 (LS393). The 614.4kHz is gated into the charge balance circuit through U513C and B.

The A/D essentially runs on its own until it has data for the processor at certain essential times during the conversion.

The event counter is a 16 bit binary counter that is used in two modes. The first mode is to count the number of charge balance pulses during signal integration. The second mode is to count the 5MHz clock during the ramp down of the single slope. Using the 5MHz clock in this manner, makes one single slope count equal to 1.1024 of charge balance counts. The resolution is thereby increased. The output of this counter is multiplexed to the data in bus, and then to the processor, 8 bits at a time.

The integration time counter consists of an 8-bit prescaler counter, U505, and an 8-bit programmable down counter U509 and U510. U505 receives its input from the lowest frequency tap of the oscillator divider. U505 drives U510 and therefore U509 with a frequency of 1200Hz. U509 and U510 are loaded from the processor. Thus, the integration time can be programmed in increments of 833μsec. This is convenient for integration periods of 16.66msec or 20msec.

The control bit latch register, U517, holds the control bits, to set up the various control and data paths on this board.

1. Bit 0—LS byte A turns on the tri-state buffer, U512, onto the data in bus.
2. Bit 1—MS byte A0 turns on the tri-state buffer, U519, onto the data in bus.
3. Bit 2—Single Slope A1 starts slope and remains at logic level 1 during the complete ramp down. The counting and the ramping will stop automatically when the ramp has crossed zero.
4. Bit 3—Parity is not used in hardware. It is used for the parity bit in software.
5. Bit 4—Force integration is normally a logic for the present

software, but it could be used to produce long integrations under direct processor control.

6. Bit 5—Event counter ACK enable normally a logic 1 in present software. It is used to sense MSB of event counter on the ACK line when an overflow occurs in a long integration.
7. Bit 6—Integrate ACK enable is normally a logic 1 in present software. ACK is asserted during the time the integration time counter is counting.
8. Bit 7—Clear A1 resets all counters to zero and thus stops all functions in progress.

A 3 input NAND gate package (U504) is used to decode so that only three of eight bits are high at any time. There are two addresses on the board.

1. $B0_H$ latches the data on the control bus into the integration time counter. The address must be present for 4msec and no longer than the integration time, otherwise it will retrigger the integration.
2. $A8_H$ latches the data on the control bus into the control bit latch on the trailing edge of the address decoding.

NOTE

The ACK line is low under the conditions described in the preceding steps 1 through 8.

6.9 FILTER/MULTIPLEXER BOARD

When reading through the theory of operation for the filter/mux board, refer to schematic diagram 30524.

The filter/mux board consists of the signal conditioning circuitry and references for the A/D board. Channel A and B electrometers are selected by the appropriate relays. These relays (K401 and K402) connect signal and ground on the electrometer module to the A/D's signal and ground inputs.

The signal FET driver amplifier (U405) is used to minimize charge injection from the gate source capacitance of the FET, into the filter when it is in use.

The input buffer (U404) is bootstrapped for linearity. It can be switched from a times one gain to a times ten gain. Two references are available for calibration; a 2V reference and a 0.2V reference.

The Electrometer Multiplexing relays switch signal and ground from the two Electrometer modules to the input of the A/D. The switching is done by K401 and K402. The relays also provide isolation between the two channels.

The ground relay K405 protects K401 and K402 from arcing or flashover when switched to the A/D. A large transient is possible when this happens due to the stray capacitance between the A/D ground and the electrometer ground R431 (10k) limiting the current during the transient. K405 is then closed to eliminate rejection problems caused by having the resistor in the ground lead.

The RC filter, which is a single pole filter, can be switched into the input of the A/D converter via relays K403 and K404. The filter consists of C408 and C409, R433, R436 and R437.

The neon bulbs DS401 and DS402 fire at approximately 85V in order to protect the capacitors in the filter from over voltage. The leakage resistance at this point, due to the neon bulbs, will be an order of magnitude less than the least significant digit, i.e., approximately 1ppm. This means the off resistance of the neon bulbs is $\geq 130G\Omega$.

The short time constant RC (C410 and C411, R436, R437, R433 and R434) is included to suppress high frequency noise from the output of the electrometer modules. When K403 and K404 are actuated, R435 and R432 limit the resulting discharge current.

Protection for the input to the A/D buffer amplifier is provided by FET's Q407 and Q412. They clamp the input to $\pm 5V$.

The op amp U405 provides a zero volt difference bias voltage for the signal FET Q409 and compensating FET Q406. Q406 provides cancellation of the charge injection due to gate-drain capacitances of these FET's into the filter capacitors C408 and C409.

FETs Q410, Q408 and Q411 provide inputs for zero, 2V and 0.2V respectively.

The A/D buffer amplifier is a X1 or X10 gain, high input impedance, low output impedance stage to couple the various inputs to the 5k input of the A/D board. The different gains are obtained by switching in the different feedback resistors. The resistors are R418 and R419. They are switched in and out by FET's Q404 and Q405. The op amp has a bootstrapped power supply of $\pm 6V$. The bootstrap supply consists of U403, Q401, C403, R404 and R407. The bootstrap ground potential is the potential at the summing junction of U404. This ground is used to reference the drive resistors of the

other input FETs Q408, Q410 and Q411. Decoupling or compensation to prevent instability in the bootstrap is provided by RCs, C403/R404 and C402/R405.

The control or logic section consists of two latches. One latch to switch relays and one latch to control the FET switches for the A/D buffer amplifier. U408, which is the FET control latch, clocks in the data that is on the control bus on the trailing edge of address $E0_H$. The output of U408 drives U406 and U407 which are open collector comparators. These comparators are used to level shift the 0 to 3V TTL signal to −15 to +5V signal to drive the FET switches.

Assignments are signals to drive the FET switches. The bit assignments are as follows:

1. Bit 0—A1 puts the buffer amplifier in X10 gain. A0 puts it in the X1 gain.
2. Bit 1—A1 turns on the signal FET (Q409).
3. Bit 2—A1 turns on the zero FET (Q410).
4. Bit 3—A1 turns on the 2V FET (U408).
5. Bit 4—A1 turns on the 0.2V FET (Q411).
6. Bit 5 not used.
7. Bit 6—A1 turns on the charge compensating FET (Q406). The software drives this bit with the complement of bit 1.
8. Bit 7 Parity. Not used in hardware.

U409, which is the relay latch, clocks in data that is on the control bus on the trailing edge of address D0.

The bit assignments are as follows:

1. B0—A0 turns on relay K401, Channel A.
2. Bit 1—A0 turns on relay K403, Channel A's filter capacitor.
3. Bit 2—A0 turns on relay K402, Channel B.
4. Bit 3—A0 turns on relay K404, Channel B's filter capacitor.
5. Bit 4—A0 turns on relay K405 ground relay.
6. Bit 5 not used.
7. Bit 6 not used.
8. Bit 7 Parity, not used.

Table 6-5. Analog Bus Connector Pin Assignments Valid for Channel A

Signal	Pin	Pin	Signal
A COM*	1	2	A COM*
33VAC	3	4	33VAC
A COM*	5	6	A COM*
BLANK	7	8	BLANK
BLANK	9	10	BLANK
CH A HI	11	12	CH A HI
CH A LO	13	14	CH A LO
A COM*	15	16	A COM*
A COM	17	18	A COM
A COM	19	20	A COM
A COM	21	22	A COM
+15VDC	23	24	−15VDC
+5VDC	25	26	+5VDC
+5VDC	27	28	+5VDC
A COM*	29	30	A1
A0	31	32	A2
A3	33	34	A4
A5	35	36	A6
LATCH ENABLE	37	38	A COM*
D00	39	40	D01
D02	41	42	D03
D04	43	44	D05
D06	45	46	D07
A COM*	47	48	/ACK
IM A0	49	50	IM A1
IM A2	51	52	IM A3
IM A4 (CH A LO)	53	54	IM A5
IM A6	55	56	IM A7
IM A8	57	58	IM A9
IM A10	59	60	IM A11
IM A12	61	62	IM A13

*Shielding ground not to be used as a current supply line.

Table 6-6. Analog Bus Connector Pin Assignment
Valid for Channel B

Signal	Pin	Pin	Signal
A COM*	1	2	A COM*
33VAC	3	4	33VAC
A COM*	5	6	A COM*
CH A HI	7	8	CH A HI
CH A LO	9	10	CH A LO
CH B HI	11	12	CH B HI
CH B LO	13	14	CH B LO
A COM*	15	16	A COM*
A COM	17	18	A COM
A COM	19	20	A COM
A COM	21	22	A COM
+15VDC	23	24	−15VDC
+5VDC	25	26	+5VDC
+5VDC	27	28	+5VDC
A COM*	29	30	A0
A1	31	32	A2
A3	33	34	A4
A5	35	36	A6
LATCH ENABLE	37	38	A COM*
D00	39	40	D01
D02	41	42	D03
D04	43	44	D05
D06	45	46	D07
A COM*	47	48	/ACK
IM B0	49	50	IM B1
IM B2	51	52	IM B3
IM B4 (CH A LO)	53	54	IM B5
IM B6	55	56	IM B7
IM B8	57	58	IM B9
IM B10	59	60	IM B11
IM B12	61	62	IM B13

*Shielding ground not to be used as a current supply line.

Table 6-7. Electrometer Control

Addresses	Byte	A/D Range
CHANNEL A, FUNCTION BYTE	000 0101 (05)	
RANGE BYTE	000 1001 (09)	
CHANNEL B, FUNCTION	000 0110 (06)	
RANGE BYTE	000 1010 (0A)	
VOLTS	1*11 0111 (FF, B7)	
VOLTS, ZERO CHECK	1*11 0011 (FB, B3)	
OHMS		
2kΩ to 20kΩ	0*01 0110 (5E, 16)	
200kΩ to 200MΩ	1*01 0110 (DE, 96)	
2GΩ to 2000GΩ	1*11 0110 (EE, B6)	
OHMS, ZERO CHECK		
2kΩ to 20kΩ	0*01 0010 (5A, 12)	
200kΩ to 200MΩ	1*01 0010 (DA, 92)	
2GΩ to 2000GΩ	1*11 0010 (EA, B2)	
AMPS		
External Feedback	1*11 0101 (FD, B5)	
2nA to 2μA	1*11 0101 (FD, B5)	
20μA to 200μA	0*11 0101 (7D, 35)	
2mA to 20mA		
External Feedback	1*11 0101 (FD, B5)	
1A	1*10 0101 (ED, A5)	
AMPS, ZERO CHECK		
2nA to 2μA	1*10 0101 (ED, A5)	
20μA to 200μA	0*10 0101 (6D, 25)	
2mA to 20mA		
External Feedback	1*10 0101 (ED, A5)	
Range Byte	**Byte**	**A/D Range**
VOLTS		
200mV	1111 0111 (F7)	200mV
2 V	1111 0111 (F7)	2 V
20 V	1101 1101 (DD)	2 V
200 V	1111 1101 (FD)	2 V
OHMS		
2 kΩ	1111 0011 (F3)	200mV
20 kΩ	1111 0011 (F3)	2 V
200 kΩ	1111 0011 (F3)	200mV
2MΩ	1111 0011 (F3)	2 V
20MΩ	1110 0111 (E7)	200mV
200MΩ	1110 0111 (E7)	2 V
OHMS		
2GΩ	1100 1101 (CD)	2 V
20GΩ	1011 0111 (B7)	2 V
200GΩ	1001 1101 (9D)	2 V
2000GΩ	1011 1101 (BD)	2 V

Table 6-7. Electrometer Control (Cont.)

Range Byte	Byte	A/D Range
AMPS		
2 A	1110 0111 (E7)	200mV
20 nA	1110 0111 (E7)	2 V
200 nA	1111 0011 (F3)	200mV
2 μA	1111 0011 (F3)	2 V
20 μA	1111 0011 (F3)	200mV
200 A	1111 0011 (F3)	2 V
2mA	0111 0111 (77)	200mV
20mA	0111 0111 (77)	2 V
2 A	1111 1110 (7E)	200mA
External Feedback	1111 0111 (F7)	2 V

*Range Disabled Bit (D06)
1 Range Byte control disabled.
0 Range Byte control enabled.
Byte data is binary.
Data in parenthesis is in hexadecimal notation.

Table 6-8. Control Data Bit Designation

Data Bit	Function Byte	Range Byte
$\overline{D00}$	K658 Ohms Reference	K603 2A
$\overline{D01}$	K601 Volts/Ohms	K662 X0.1/X0.01 Output
$\overline{D02}$	K656 Volts/Ohms, Zero Check	K652 2MΩ/20kΩ Feedback
$\overline{D03}$	Not Used	K661 X1 Output
$\overline{D04}$	K655 Amps, Zero Check	K653 200MΩ Feedback
$\overline{D05}$	K659Ω Input Voltage Limit	K660 X0.1 Output
$\overline{D06}$	Range Disable	K654 20GΩ Feedback
$\overline{D07}$	K657 20kΩ Feedback	K651 200Ω Feedback

*Relay designation refer to schematics 30522 and 30523.

SECTION 7
MAINTENANCE

7.1 INTRODUCTION

This section contains information necessary to maintain, calibrate and troubleshoot the Model 619. Fuse replacement, line voltage and frequency selection and internal programming procedures are also included.

WARNING

The procedures included in this section are intended for use only by qualified personnel. Do not perform these procedures unless qualified to do so. Some of the steps may expose you to potentially lethal voltages that could result in personal injury or death if contacted.

7.2 LINE VOLTAGE SELECTION

The Model 619 may be operated from 90-110V, 105-125V, 190-220V or 210-250V, 50 or 60Hz power sources. The low (90-125V) or high (180-250V) voltage range is marked on the rear panel. To change the line voltage, or to verify the present setting, use the following procedure.

WARNING

Disconnect the Model 619 from the power line and all other sources before removing the top cover.

1. Remove the two screws that secure the top cover to the rear panel and carefully lift the cover away from the instrument.
2. Remove the power supply shield. Note that the shield is secured to the power supply PC board by clips, so some effort may be required to free the shield from the board.
3. Set the two switches to the correct positions, as indicated in Table 7-1 and Figure 7-1. Note that the switch positions are also marked on the power supply shield for reference.
4. Install a fuse that is consistent with the operating voltage, as described in paragraph 7.3.

CAUTION

The correct fuse type must be used to maintain proper instrument protection.

5. Replace the power shield.
6. Replace the top cover and secure it with the two screws removed earlier.

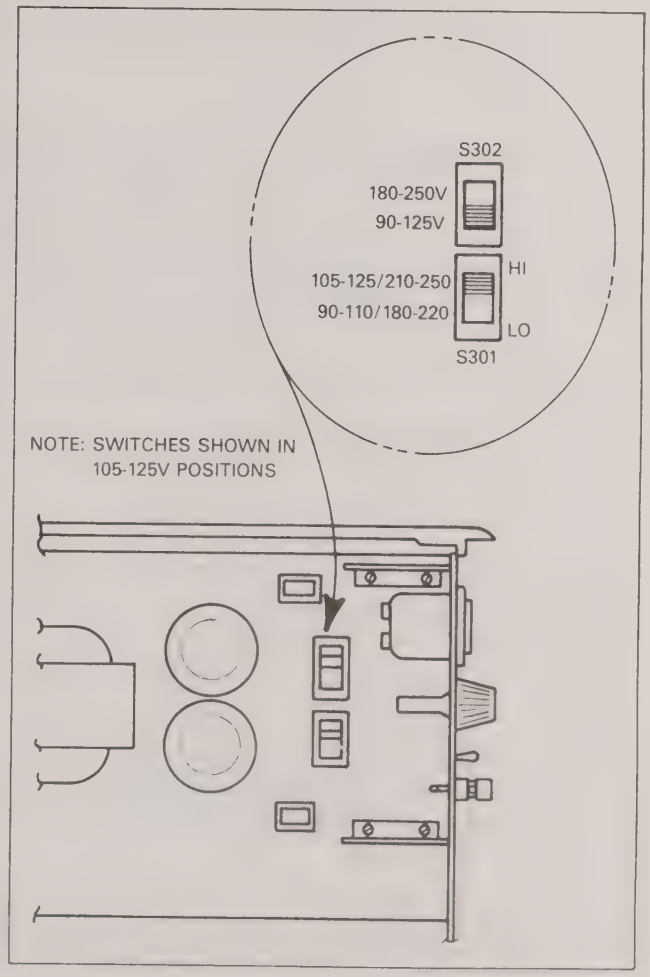


Figure 7-1. Line Voltage Selection Switches

Table 7-1. Line Voltage and Fuse Selection

Line Voltage	S301 HI-LO Switch	S302 110—220V Switch	Fuse Type	Keithley P/N
90V—110V	LO	110V	3AG, SLO BLO, 250V, 1A	FU-10
105V—125V	HI	110V	3AG, SLO BLO, 250V, 1A	FU-10
180V—220V	LO	220V	3AG, SLO BLO, 250V, ½A	FU-4
210V—250V	HI	220V	3AG, SLO BLO, 250V, ½A	FU-4

7.3 FUSE REPLACEMENT

A line fuse protects the power line input of the instrument from excessive current. In a similar manner, a fuse protects each 2A input of the electrometer module. To replace either fuse, use the following procedure.

1. Turn off the power and disconnect all sources from the instrument.
2. Remove the fuse by pressing in on the fuse carrier and rotating it counter-clockwise. Pull the fuse and the carrier free of the holder.
3. Replace the fuse with the recommended type. For the line fuse, use the type specified in Table 7-1, depending on the selected line voltage. For the 2A current fuse, use the following fuse: 2A, normal blow, 250V, 3AG, Keithley part number FU-13.

CAUTION

Do not install a fuse with a higher rating than specified or instrument damage may occur. If the instrument consistently blows fuses, the problem must be rectified before continuing operation.

4. Install the fuse and carrier in the holder by reversing the above procedure.

7.4 INTERNAL PROGRAMMING

An internal DIP switch set (S801) located on the isolator board, controls beeper operation, reading rate, external triggering, and 50-60Hz line frequency selection. To gain access to this switch, it will be necessary to remove the top cover from the instrument.

WARNING

Disconnect the line cord and all sources from the instrument before removing the top cover.

Remove the two screws securing the cover to the rear panel and then lift the cover free of the instrument.

The DIP switch set is located on the isolator board at the back edge near the fan assembly. The isolator board is the only one with a ribbon cable at the front edge. To program the various functions, set the switch to the appropriate position, as described in the following paragraphs. The switch is shown in Figure 7-2.

NOTE

The switch positions are read only upon power up. Thus, power to the instrument will have to be cycled to change these operating modes.

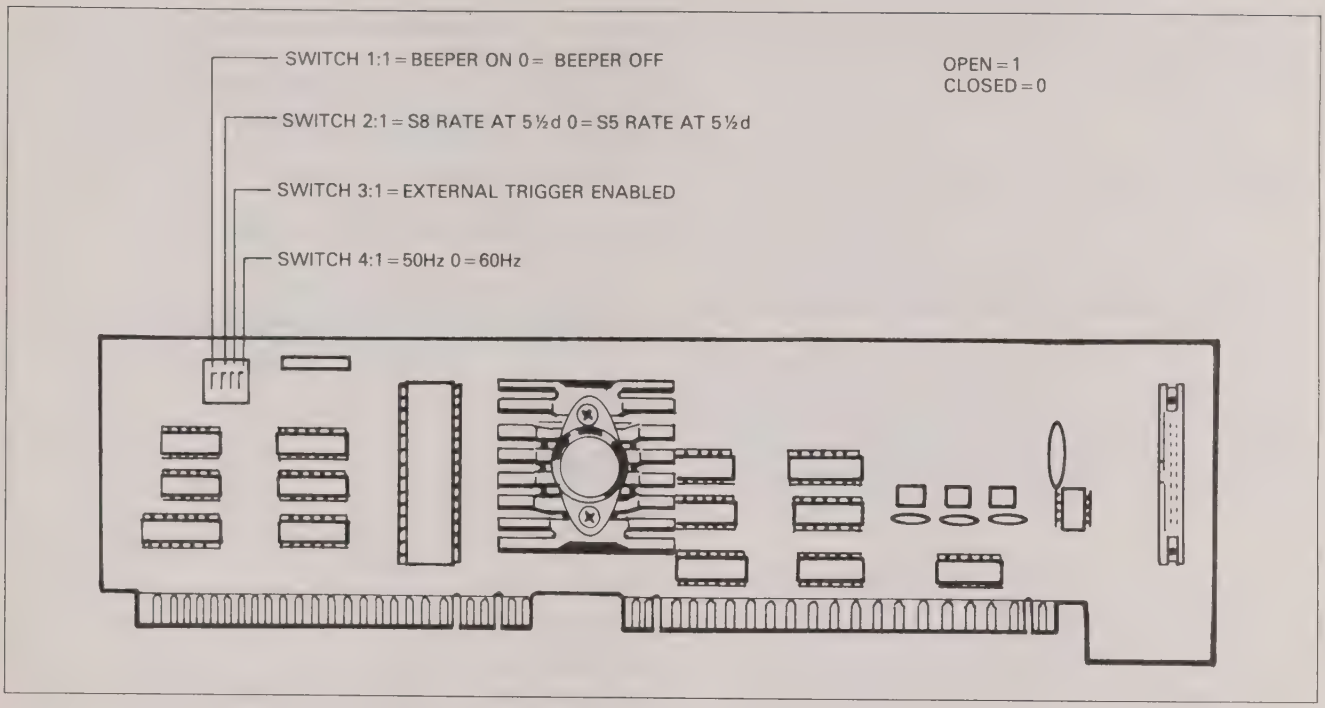

SWITCH 1:1 = BEEPER ON 0 = BEEPER OFF
SWITCH 2:1 = S8 RATE AT 5½d 0 = S5 RATE AT 5½d
SWITCH 3:1 = EXTERNAL TRIGGER ENABLED
SWITCH 4:1 = 50Hz 0 = 60Hz
OPEN = 1
CLOSED = 0

Figure 7-2. Isolation Board and Switches

7.4.1 Beeper Programming

If enabled, the beeper sounds when pressing a front panel button to indicate that the instrument has acknowledged a mode change. The beeper may be controlled by setting switch 1 to one of the following positions:

Beeper off: 1 (open)
Beeper on: 0 (closed)

7.4.2 Reading Rate Selection

When the instrument is in the 5½ digit resolution mode, as selected from the front panel, switch 2 on S801 may be used to program one of two reading rates: 2.41 readings per second, and 0.3 readings per second. These rates correspond to the S5 and S8 modes respectively (refer to paragraph 3.10.5). Program the 5½ digit resolution reading rate by setting switch 2 as follows:

S5 rate (2.41 readings per second): 0 (closed)
S8 rate (0.3 readings per second): 1 (open)

7.4.3 External Trigger Mode

The Model 619 may be externally triggered to take readings by applying an appropriate trigger pulse to the rear panel EXTERNAL TRIGGER input (paragraph 2.16). In order to use external triggering, switch 3 must be in the correct position as follows:

External trigger disabled: 0 (closed)
External trigger enabled: 1 (open)

Once switch 3 is in the enabled position, the instrument will go into the external trigger mode the next time the RESOLUTION button on the front panel is pressed.

7.4.4 Line Frequency Selection

The Model 619 can be operated from 50 or 60Hz power sources. Switch 4 on S801 should be set to the 50 or 60Hz position to program the unit for the operating frequency. Doing so sets the integration period to the appropriate value (16.66msec, 60Hz or 20msec, 50Hz) in the S1 through S3 rate modes (see paragraph 3.10.5). If the instrument is incorrectly programmed, noiser readings may result.

Program the line frequency by setting switch 4 as follows:

50Hz: 1 (open)
60Hz: 0 (closed)

7.5 CALIBRATION

Perform the following procedures and make the adjustments indicated to calibrate the Model 619 Electrometer/Multimeter, and the Model 6194 Electrometer Module(s). Calibration of the Model 6194 requires installation in a Model 619 mainframe. Therefore, the following procedures include calibration of the module as part of the entire instrument. Calibration should be performed yearly (every 12 months) or whenever performance verification (see Section 5) indicates that the instrument is out of specifications.

NOTE

Calibration of the Model 619 requires currents and impedances outside the ranges normally encountered in calibration laboratories. Due to the need for special handling, high level technical expertise, and non-standard test equipment, it is strongly recommended that the Model 619 be returned to the factory for service and/or calibration.

7.5.1 Environmental Conditions

Calibration should be performed under laboratory conditions having an ambient temperature of 23°±1°C, and a relative humidity of less than 70%. If the instrument has been subjected to temperatures outside of this range, or to higher humidity, allow one hour minimum for the instrument to stabilize at the specified environmental conditions before beginning the calibration procedure.

7.5.2 Recommended Test Equipment

Test equipment for calibration is listed in Table 7-2. Alternate test equipment may be used. However, the accuracy of the alternate test equipment must meet specifications listed below:

Voltage Sources (±20ppm)
190.0000mV
1.900000V
19.00000V
199.0000V

Current Sources (±200ppm)
19.000mA
190.00μA
1.9000μA
19.000nA

Calibration Resistance
19kΩ ±100ppm
19GΩ ±1000ppm

Table 7-2. Recommended Calibration Equipment

Description	Output	Accuracy	Mfr.	Model
DC Calibrator	1.999999V 19.99999V 199.9999V	0.002% or 20ppm	Fluke	343A
Current Source	10μA-2A	0.01%	Valhalla	2500
Decade Resistor	120kΩ/10k-Steps	50ppm	ESI	SR-1010
	110MΩ/1M-Steps	50ppm	ESI	SR-1050
Resistor*	10GΩ	1000ppm	Keithley	R-289-10G
Resistor*	100GΩ	1000ppm	Keithley	R-289-100G
Teraohmmeter**		0.08%	Guildline	9520
Guarded Test Fixture				

*Used to construct nominal 19GΩ test fixture.
**Used to measure 19GΩ test fixture resistance.

7.5.3 Calibration Cover Installation

Calibration should be performed using the Model 6195 calibration cover (see Figure 7-3). This cover permits access to Model 619 and to Model 6194 adjustments, while allowing the instrument to reach normal internal operating temperature. Install the cover as follows:

WARNING
To prevent a shock hazard, remove the line cord and all test leads from the instrument before removing the top cover.

1. Turn the power off and disconnet the line cord.
2. Remove the two screws holding the top cover. These screws are located on the rear panel.
3. Grasping the top cover at the rear, carefully lift it off the instrument.
4. Install the calibration cover on the Model 619.

7.5.4 Calibration Sequence

The sequence of calibration adjustments is as follows:

1. Input amplifier zero.
2. A/D reference supply calibration.
3. Multiplier calibration.
4. Amps calibration.
5. Ohms reference calibration.

7.5.5 Calibration Procedure

Perform the following procedures and make the adjustments indicated to calibrate the Model 619. The location of the calibration pots is indicated on the Model 6195 Calibration Cover (see Figure 7-3).

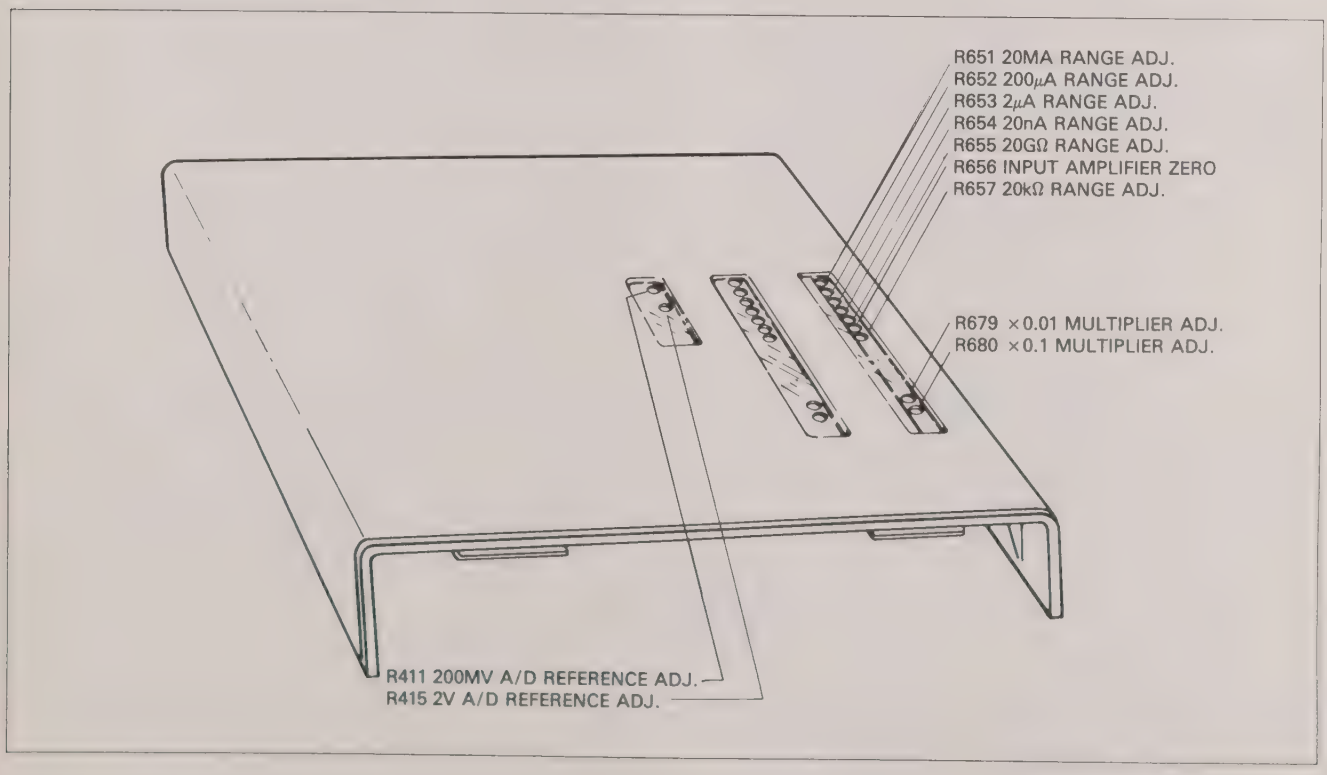

R651 20MA RANGE ADJ.
R652 200μA RANGE ADJ.
R653 2μA RANGE ADJ.
R654 20nA RANGE ADJ.
R655 20GΩ RANGE ADJ.
R656 INPUT AMPLIFIER ZERO
R657 20kΩ RANGE ADJ.
R679 ×0.01 MULTIPLIER ADJ.
R680 ×0.1 MULTIPLIER ADJ.
R411 200MV A/D REFERENCE ADJ.
R415 2V A/D REFERENCE ADJ.

Figure 7-3. Calibration Cover and Adjustment Locations

WARNING

The shield surrounding calibration potentiometers is connected to signal common. Calibration sources should not be floated more than 30V above ground or a shock hazard will result.

NOTE

Zero correct must be performed on the lowest range of the selected function. Do not zero correct while in the autorange mode.

1. Input Amplifier Zero: Place the instrument in zero check, channel A, volts and manual ranging. Should the instrument have only one electrometer module, it must be located in position A (channel A). Set the Model 619 to the 200mV range and adjust R656 for a display reading of 0.00 −3 within ±1 count.

NOTE

Zero Correct should not be used prior to this step.

2. 200mV A/D Reference Supply Calibration: Using the DC calibrator and 10:1 divider, apply +190.00mV to the input of the electrometer. After actuating zero correct, disable zero check and adjust R411 for a display reading of +190.00 −3 within ±1 count. Refer to Figure 7-4 for connections.
3. 2V A/D Reference Supply Calibration: Uprange the Model 619 to the 2V range, and apply +1.9000V to its input. Adjust R415 for a display reading of +1.9000 +0 to within ±1 count. Refer to Figure 7-5 for connections.

NOTE

Steps 2 and 3 above need not be repeated for channel B.

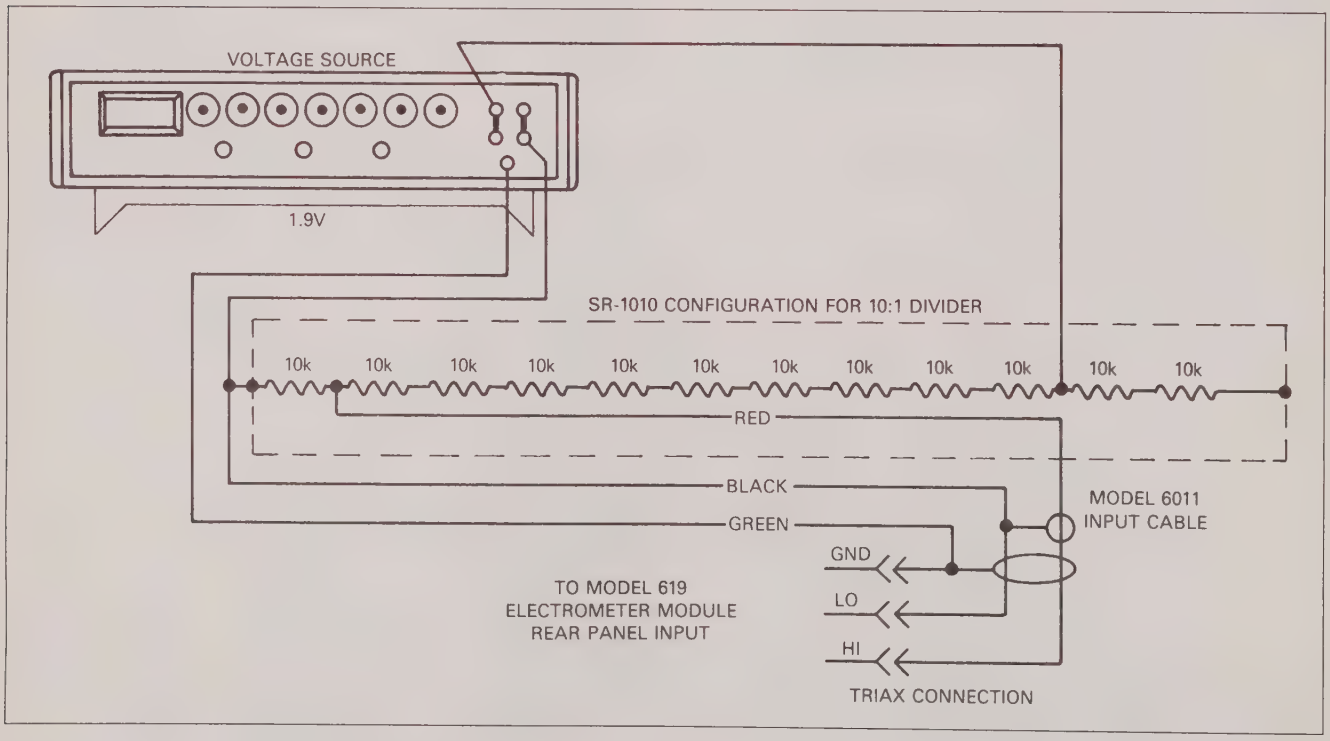


Figure 7-4. 200mV Reference Calibration Configuration

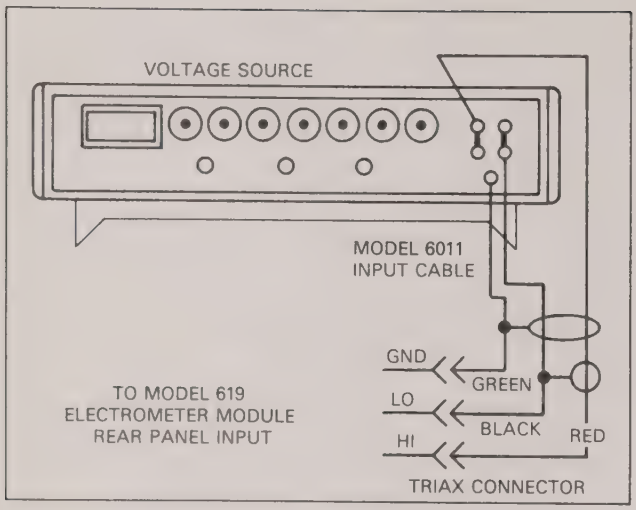


Figure 7-5. 2V Reference Configuration and Multiplier Calibration

4. X0.1 Multiplier Calibration: Uprange the Model 619 to the 20V range and apply +19.000V to its input. Adjust R680 for a display of +19.000 +0 to within ±1 count.
5. X0.01 Multiplier Calibration: Uprange the Model 619 to the 200V range and apply +190.00V to its input. Adjust R679 for a display reading of +190.00 +0 to within ±1 count.
6. 20mA Range Calibration: Zero check the Model 619 and set it to the amps function. Uprange to the 20mA range and verify a display reading of 19.000 −3 using zero correct if necessary. Disable zero check and apply a +19.000mA input, adjust R651 for a display reading of 19.000 −3 to within ±2 counts. Refer to Figure 7-6 for input connections.

NOTE

For a valid zero check reading, the input current must be less than 100μA.

7. 200μA Range Calibration: Zero check the Model 619 and downrange to the 200μA range. Apply +190.00μA to the input of the Model 619, disable zero check and adjust R652 for a display reading of +190.00 −6 within ±2 counts.
8. 2μA Range Calibration: Zero check the Model 619 and downrange to the 2μA range. Apply +1.9000μA to the input of the Model 619, disable zero check and adjust R653 for a display reading of +1.9000 −6 to within ±1 count.
9. 20nA Range Calibration: Zero check the Model 619 and downrange to the 20nA range. Apply +19.000nA to the input of the Model 619, disable zero check and adjust R654 for a display reading of +19.000 −9 to within ±2 counts. Refer to Figure 7-7 for connections.
10. 20kΩ Range (Ohms Reference) Calibration: Zero check the Model 619 and set the ohms function. Select the 20kΩ range and verify a display reading of 0.000 +3 using zero correct if necessary. Connect the 19kΩ calibration resistor to the input of the Model 619, disable zero check and adjust R657 for a display reading of 19.000 +3 to within ±1 count. Refer to Figure 7-8.
11. Using the teraohmmeter, measure the actual resistance of the 19GΩ resistor. This resistor must be placed in a shielded guarded enclosure, as discussed in paragraph 7.5.6. Use the actual value in the following step.

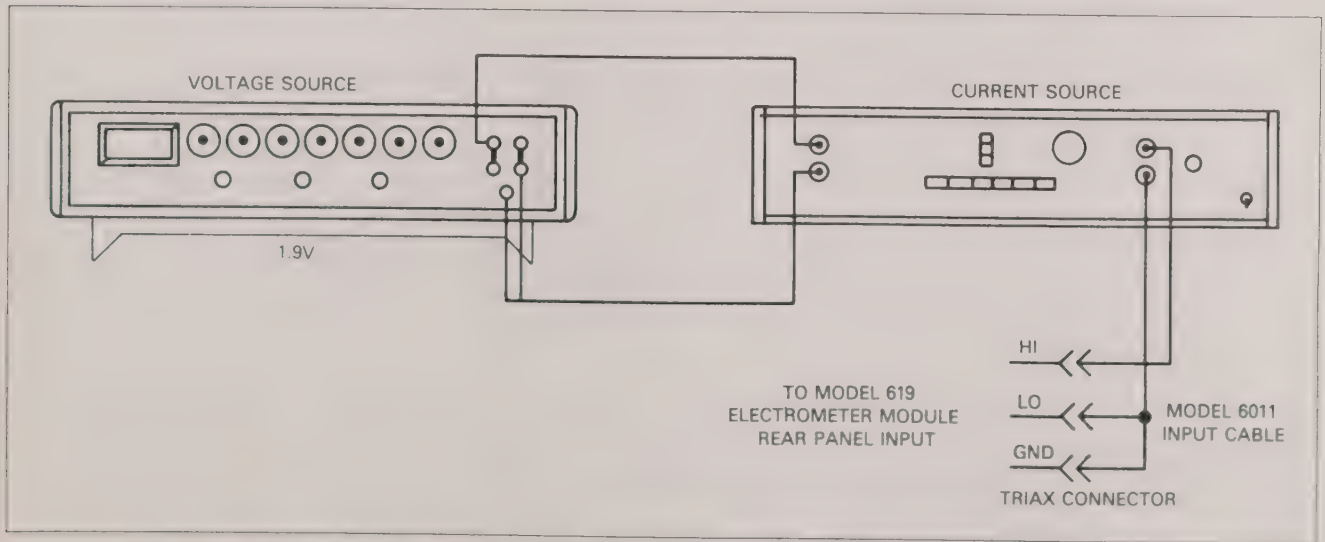


Figure 7-6. 2μA, 200μA and 20mA Range Calibration Configuration

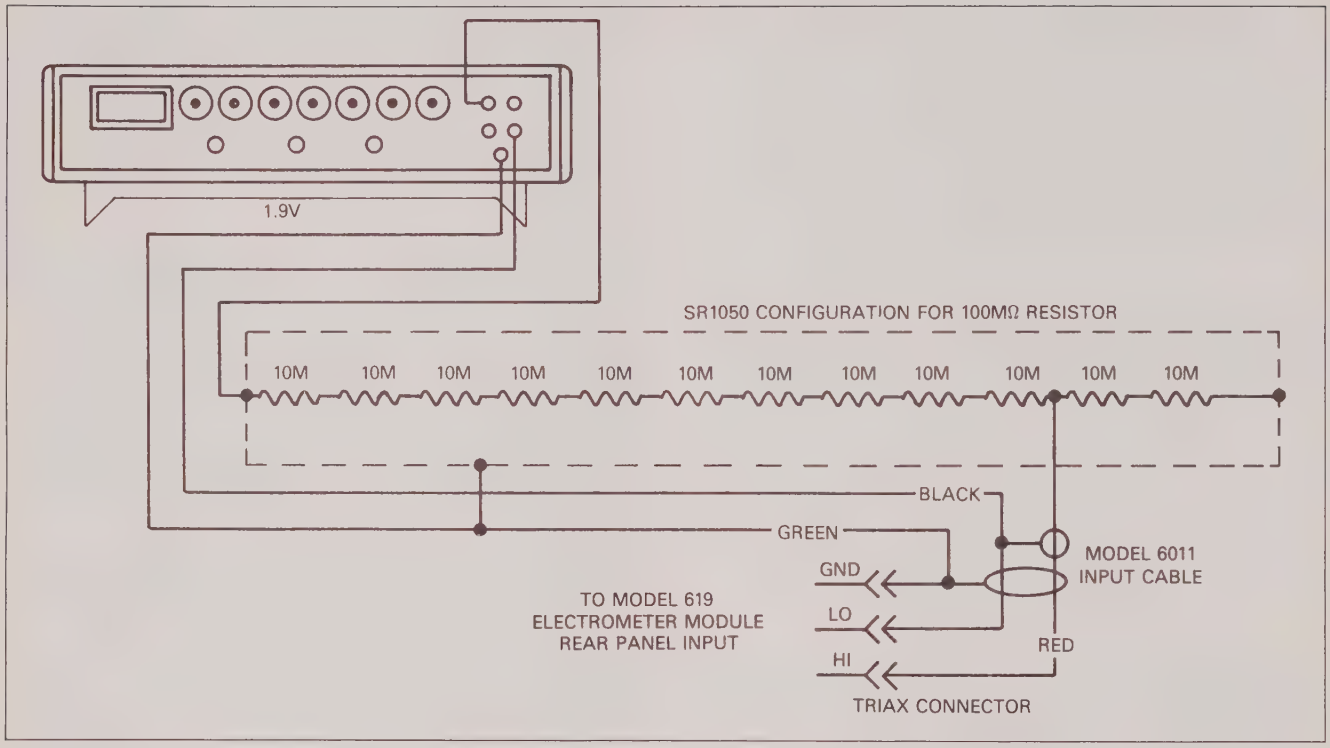


Figure 7-7. 20nA Range Calibration Configuration

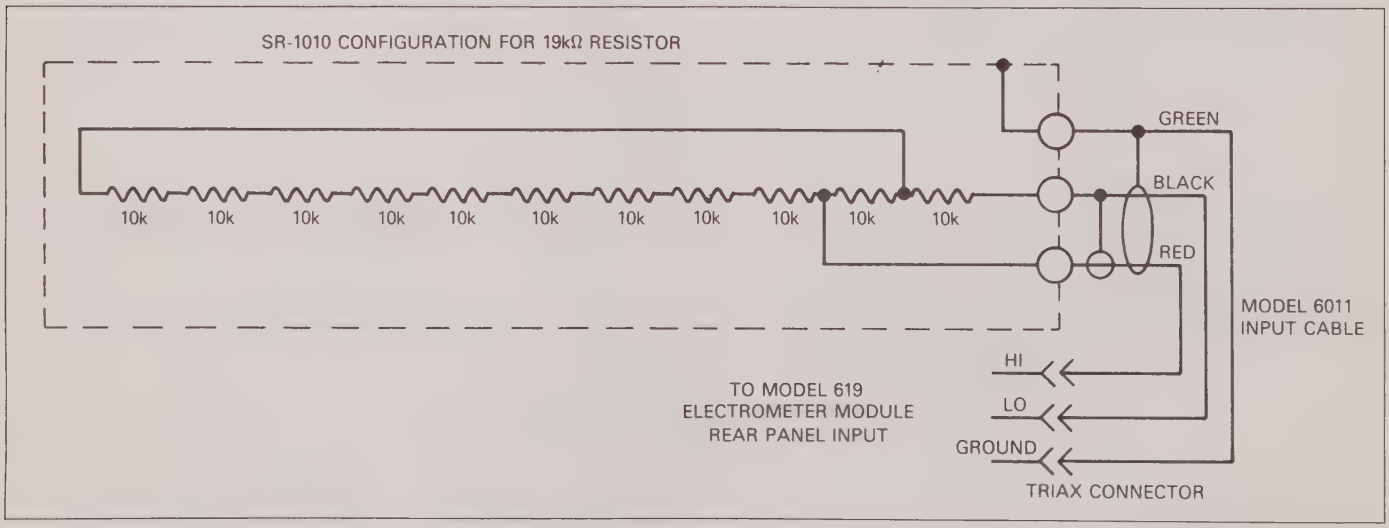


Figure 7-8. 20kΩ Range Calibration Configuration

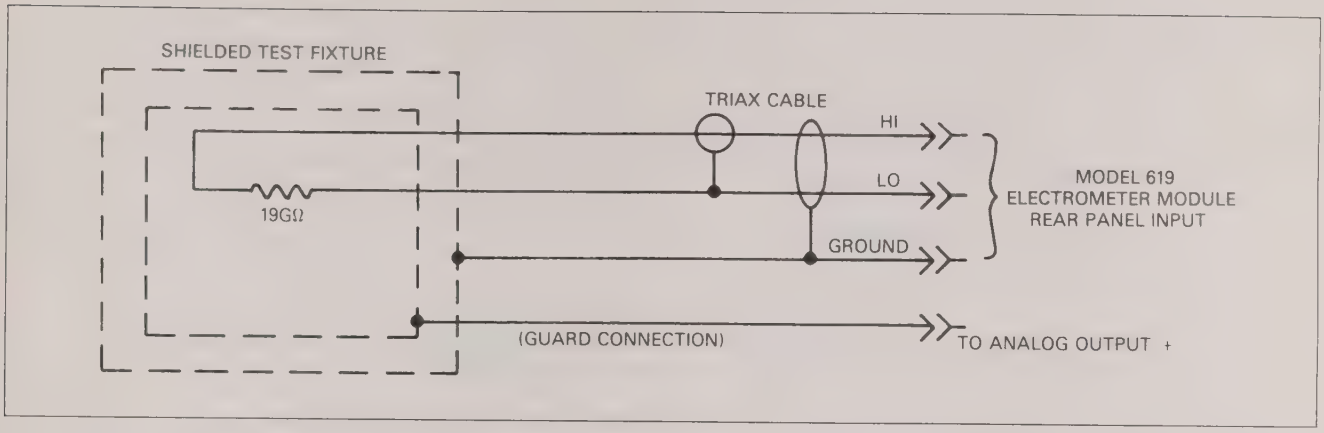


Figure 7-9. 20GΩ Range Calibration Configuration

12. 20GΩ Range Calibration: Zero check the Model 619 and uprange to the 20GΩ range. Connect the 19GΩ calibration resistor to the input of the Model 619, disable zero check, and adjust R655 for a display reading equal to the value obtained above, ±15 counts. Refer to Figure 7-9 for connections.
13. Range Verification: After range calibration perform the verification procedures. Refer to Section 5 for these procedures.
14. Channel B Calibration: If a channel B electrometer is installed in the Model 619, steps 1 and 4 through 13 must be repeated for this channel. The calibration potentiometers are the same as those for channel A.

7.5.6 Shielded Fixture Construction

The calibration fixture has a nominal value of 19GΩ. Its resistors must be accurate to 1000ppm.

The following items are necessary for this fixture.

1. Two 10.0GΩ resistors, Keithley part number R-289-10G.
2. One 100.0GΩ resistor, Keithley part number R-289-100G.
3. Two enclosed chassis boxes one to be placed inside the other and insulated from each other.
4. A triax connector, Keithley part number CS-181.
5. Banana jack, Keithley part number BJ-11.
6. Model 6191 Guarded Input Adapter.
7. Model 7024-1 triax cable (1 ft. long, male-to-male connector).

When constructing this fixture, the following factors must be taken into account.

1. To decrease settling time and to assure accurate calibration, an internal guard is recommended. The guard must be isolated from the surrounding case. See Figure 7-10.
2. To further minimize inaccuracies, current leakage paths to ground (or guard) must be minimized. This requires the use of low leakage insulating materials (such as Teflon) for construction and the use of special cleaning agents (such as Freon) to clean the components and insulators after construction.
3. Do not touch the body of the resistors, or any other high impedance nodes, as doing so could contaminate the components, giving erroneous results.

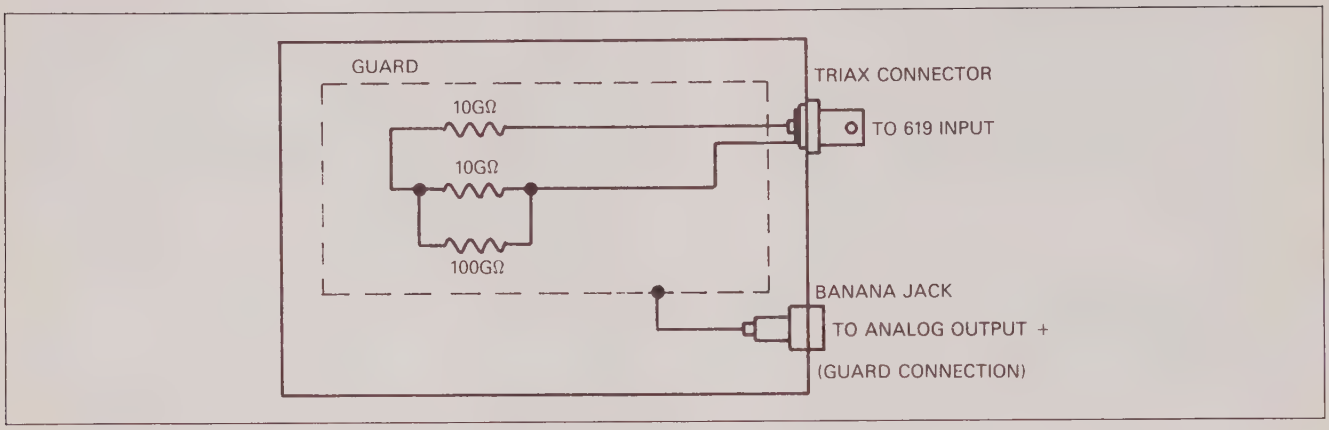


Figure 7-10. Shielded Fixture Construction (for Calibrating 20GΩ Range)

7.6 SPECIAL HANDLING OF STATIC-SENSITIVE DEVICES

CMOS devices operate at very high impedance levels for low power consumption. As a result, any static charge that builds up on your person or clothing may be sufficient to destroy these devices, if they are not handled properly. Table 7-3 lists static-sensitive devices used in the Model 619. When handling these devices, use the precautions below to avoid damaging them.

Table 7-3. Static Sensitive Devices

Designation	Keithley Part Number
U202, U204, U207	IC-141
U807	LSI-28
U905	LSI-27
U906	PRO-114-*
U907, U915, U924	PRO-115-*
U913	LSI-26
U919, U920, U922, U923	LSI-15

*Last two digits define software revision level.

1. The ICs listed in the table should be transported and handled only in containers designed to prevent static build-up. Typically, these parts will be received in anti-static containers of plastic or foam. Keep these devices in their original containers until ready for installation.
2. Remove the devices from their protective containers only at a properly grounded work station. Also ground yourself with a suitable wrist strap.
3. Handle the devices only by the body; do not touch the pins.
4. Any printed circuit board into which the device is to be inserted must also be grounded to the bench or table.
5. Use only anti-static type solder suckers.
6. Use only grounded tip soldering irons.
7. Once the device is installed on the PC board, it is normally adequately protected, and normal handling can resume.

7.7 HANDLING AND CLEANING PRECAUTIONS

When troubleshooting or otherwise working inside the instrument, care should be taken not to indiscriminately touch PC board traces and open wires to avoid contaminating them with body oils for other foreign matter. In particular, there is one area within the Model 619 that has numerous high impedance nodes where contamination could cause degraded performance. The input amplifier circuitry located on the electrometer module PC-523 is particularly sensitive to contamination.

The same general precautions apply when replacing parts in these areas. When unsoldering and soldering parts, be careful not to spread the flux around the board to adjacent areas. After replacing parts, or if contamination is suspected, use the following procedure to clean the affected area.

1. Using a squeeze bottle, carefully apply clean, uncontaminated methanol to the area to be cleaned. Use sufficient solution to thoroughly wet the circuit board.

2. Using a small, clean brush, wipe the area thoroughly until it is free of flux or contaminants. In some cases, it may be helpful to tilt the board at an angle and brush contaminants away from the affected area, allowing contaminated residue and methanol to run off the board.
3. Wash the area again with fresh, clean methanol.
4. Once the area is thoroughly cleaned, it should be dryed with pressurized dry, clean air or nitrogen. Do not use compressed air from an ordinary compressor, as oil particles in the air could contaminate the circuit board.
5. After cleaning or parts replacement, check to see that any components connected to the Teflon insulators are not physically touching the board or adjacent parts.

7.8 DISASSEMBLY INSTRUCTIONS

If it is necessary to troubleshoot the instrument or replace a component, use the following disassembly procedure. An exploded view of the instrument may be found in Figure 7-11.

WARNING
Disconnect the line cord and any test leads from the instrument before disassembly.

1. Remove the top cover as follows:
   A. Remove the two screws that secure the top cover to the rear panel.
   B. Grasp the top cover at the rear and carefully pull up until the tabs at the front of the cover clear the front panel. The cover may then be pulled completely clear.
   C. To replace the top cover, reverse the above procedure. Be sure to install the tabs at the front of the cover before completely installing it.
2. Remove the various circuit boards from the mother board as follows:
   A. Remove the A/D, filter/multiplexer and processor boards by pulling them out of their respective sockets on the mother board.
   B. Remove the isolator board by first disconnecting the ribbon cable at the board and then removing the board from the mother board.
   C. Remove the electrometer module(s) by removing the small screw in the lower right corner of each module panel on the rear of the instrument. Now remove the module by pulling up until it is free of the mother board.
   D. Remove the IEEE-488 interface board (if installed) by removing the small screw on the rear panel in the lower right corner of the module and then pulling the board free of the mother board.
3. Remove the power supply as follows:
   A. Remove the power supply shield by pulling it free of the clips that secure it to the circuit board.
   B. Disconnect the two plugs in the vicinity of the line voltage selection switches.
   C. Remove all screws that secure the board to the bottom cover. These include the two screws near the front of the instrument, the four screws that secure the power transformer, and the two larger screws that secure the rear panel bracket to the circuit board.
   D. Use a screwdriver to pry the power supply free of the two plugs.
   E. Remove the nut that secures the green ground wires to the rear panel. Remove the ground wires from the screw.
   F. Remove the small screw remaining on the bracket closest to the fan. Guide the wire going to the fan under the bracket until it is free of the supply.
   G. The power supply assembly should now be free of the mother board.
4. Remove the mother board as follows:
   A. Remove the screws that secure the mother board to the bottom cover. Do not remove the screws that secure the small angle brackets to the rear of the mother board.
   B. Remove the mother board by lifting it free of the case.
5. Remove the fan by removing the two screws from the bottom case (accessible from underneath) and lifting the fan assembly free of the case.
6. Remove the display board by removing the nuts that secure it to the front panel and remove the board.
7. Reassemble the instrument by reversing the above procedure. When assembling the instrument, note the following:
   A. Be sure that all screws are properly installed.
   B. Make certain that all boards, including the power supply board, are properly seated in their respective sockets.
   C. Make sure that all ground wires are properly connected to the grounding screws on the rear panel of the power supply. The ground wire going to the mother board must also be in place.

WARNING
All ground wires must be properly replaced to ensure continued protection against possible shock hazards.

   D. When installing the power supply, make sure that no wires become pinched between the board and bottom case.
   E. Be sure to install the power supply shield.

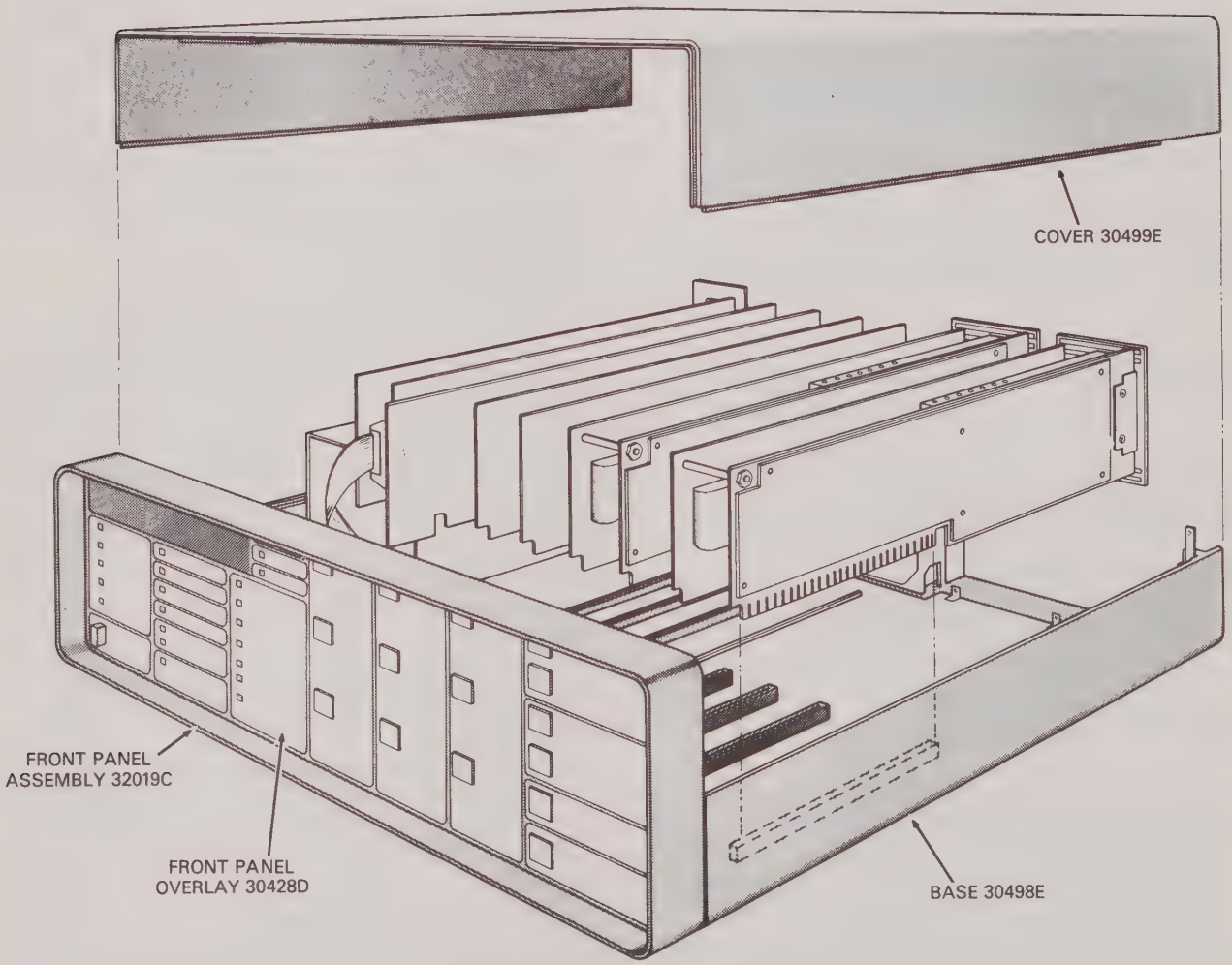


Figure 7-11. Model 619 Exploded View (sheet 1 of 2)

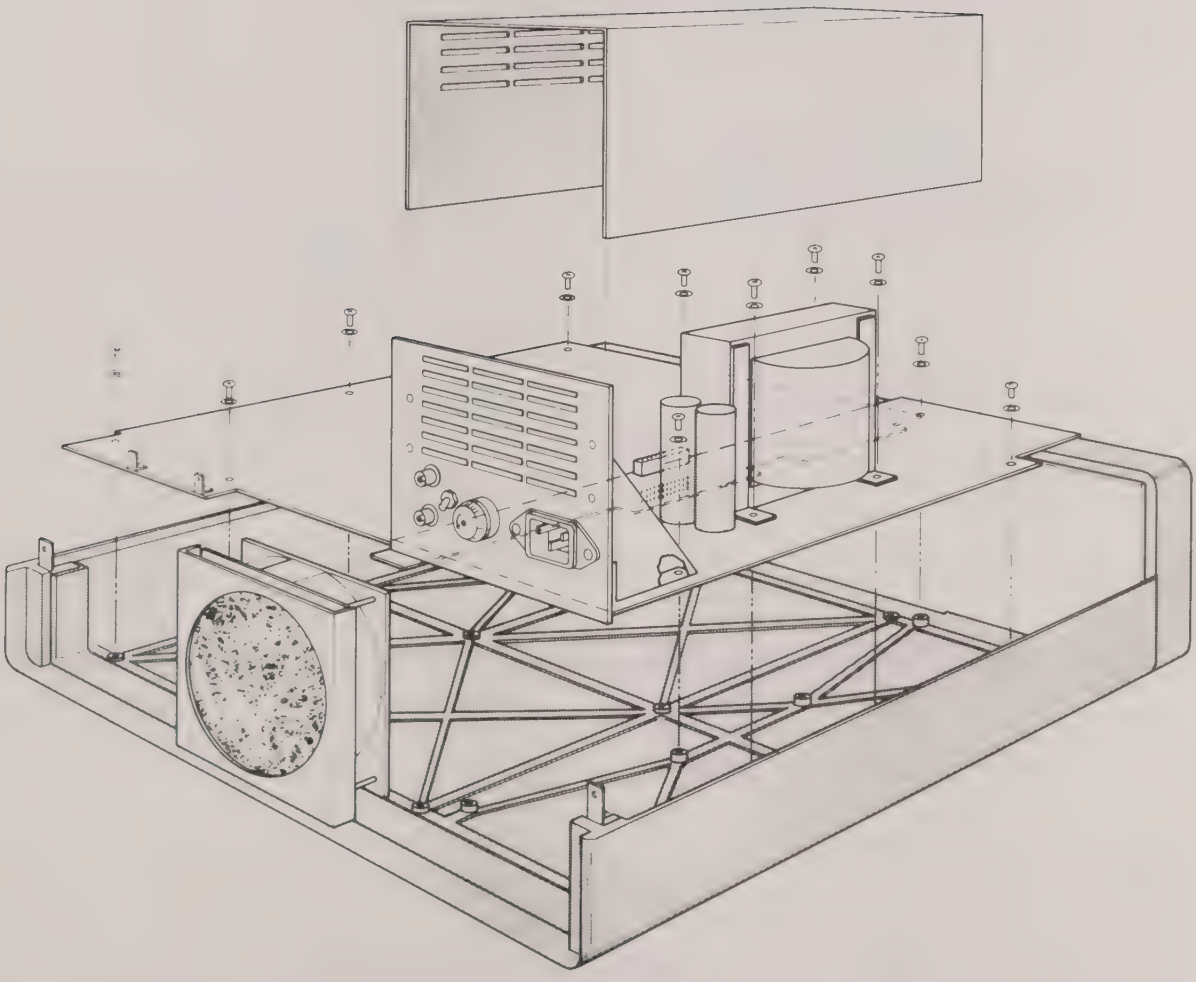


Figure 7-11. Model 619 Exploded View (sheet 2 of 2)

7.9 TROUBLESHOOTING

The troubleshooting information contained in this section is intended for qualified personnel having a basic understanding of analog and digital circuitry. The individual should also be experienced at using typical test equipment, as well as ordinary troubleshooting procedures. The information presented here has been written to assist in isolating a defective circuit section. Isolation of the specific component is left to the technician. Note that schematic diagrams and component layout drawings, which are an essential aid in troubleshooting, are located at the end of Section 8.

WARNING

The electrometer board shields are connected to input common. Thus, the shield can float up to ±250V above chassis ground, depending on the input signal.

7.9.1 Recommended Test Equipment

Success in troubleshooting complex equipment like the Model 619 depends not only on the skill of the technician, but also relies on the use of accurate, reliable test equipment. Table 7-4 lists the minimum recommended equipment for troubleshooting the Model 619. Other equipment such as logic analyzers and capacitance meters could also be helpful, especially in difficult situations.

7.9.2 Power-Up Self Test

Upon power-up the Model 619 performs the following self tests.

1. LED Test—In this self test the user observes that all LED's are on for approximately one second.
2. ROM Test—The Model 619 tests the ROM circuitry during the LED test by performing a cyclic redundance check

Table 7-4. Recommended Troubleshooting Equipment

Equipment	Use
DMM with 0.015% basic DC accuracy, 10MΩ input impedance (Keithley Model 197 or equivalent).	Power supply and DC voltage checks; analog signal tracing; continuity; static logic levels.
Dual-trace, triggered-sweep oscilloscope, DC-50MHz bandwidth.	Digital and analog waveform checks.

Table 7-5. Power-Up Checks

Condition	Remarks
Display blank, no LED's or beeper.	Check line fuse F301 for continuity. Check rear power switch (S303). Remove the IEEE-488 interface board. If the problem is corrected, replace the IEEE-488 interface board. If the problem continues with the interface board removed, leave the interface board disconnected from the mother board until the problem has been corrected. Check power supplies (see power supply checks paragraph 7.9.4).
The Model 619 does not complete the power up cycle. The LEDs lock up or flash between functions.	Carefully activate all front panel switches to ensure no two switches close at the same time. Proceed to Power Supply Checks paragraph.

(CRC). If something is wrong in the RAM circuitry it will be noted by the channel A, channel B, ratio A/B and difference A-B LED's blinking on and off.

3. RAM Test—The Model 619 tests the RAM circuitry during the LED test. If the test discovers a defective chip it will be indicated by the appropriate LED blinking as follows:

Low	BYTE	low	1k	RAM	U919	CH.A
High	BYTE	low	1k	RAM	U920	CH.B
Low	BYTE	high	1k	RAM	U922	RATIO
High	BYTE	high	1k	RAM	U923	DIFF

4. PC Board Functionality
   A. The CPU writes and reads from each PC board connected in the mother board to verify the board operation and Model 619 configuration.
   B. If any circuit board is not present or is defective a message will be displayed on the front panel display as to which board is defective.
5. OPTO Test—Eight attempts are made to send data across the opto-isolators (AT1-AT4). If the data is not sent correctly after the eight attempts the display message "SND E" will occur and the transmission is attempted eight more time. This process continues until the data is correct.
   Eight attempts are made to receive data across the opto-isolators (AT1-AT4). If the data is not received correctly after eight attempts the display message "REC E" will occur and the transmission is attempted eight more times. This process continues until the data is correct. Additional power-up checks are listed in Table 7-5.

7.9.3 Prepower-Up Visual Checks

WARNING
To prevent a shock hazard, remove the line cord and all test leads from the instrument before removing any cover.

Some problems may be found by visually checking the circuit boards and connectors. View the Model 619 from the front panel when referring to the left or right of the instrument.

1. Inspect all mother board connectors (CS-381) for breaks or splits in the connectors. Replace any connector that is determined to be faulty.
2. Inspect the power connector (J302) of the fan (FN-7).
3. Inspect all PC boards for proper seating in the connectors (press down firmly into connector).

7.9.4 Power Supply Checks

Check the digital and analog power supplies as per Tables 7-6 and 7-7. The analog power supply with its connectors is located on the left side of the instrument. Connector J305 (12 pin) is located toward the front of the instrument. Connector J304 (12 pin) is located toward the rear of the instrument beneath the power supply shield.

Table 7-6. Digital Supply Checks

Condition	Remarks
9.5V unregulated J304 pins 6-9 referenced to pins 1-5 (digital common).	Check associated circuitry (CR301, C302, C303, R302, etc.).

Table 7-7. Analog Supply Checks

Condition	Remarks
+15V J305 pin 8 referenced to pins 5-7 (analog common).	Check associated circuitry (VR302, CR303, C309, C307, C306, R305).
−15V J305 pin 9 referenced to pins 5-7 (analog common).	Check associated circuitry (CR303, VR301, C308, C305, C304, R303).
+5V J305 pins 10-12 referenced to pins 5-7 (analog common).	Check associated circuitry (CR302, VR303, C310, C311, C312, R304).
33VAC J305 pins 1 and 2 referenced to pins 3 and 4.	Transformer T301
If all power supplies are producing the correct voltage proceed to CPU board checks, paragraph 7.9.5.	

7.9.5 CPU Board Checks

Check out the CPU board (PC-518) by using the procedure in Table 7-8. Checks include the presence of the 5V digital supply as well as the CPU clock (4MHz).

7.9.6 Isolator Board Checks

Check the isolator board by using the procedure listed in Table 7-9. Isolator waveforms are shown in Figures 7-12, 7-13 and 7-14. If the isolator outputs are not transmitting the correct information, replace the isolator board.

Table 7-8. CPU Board Checks

Condition	Remarks
5V power supply test point 8 (TP8) 5V referenced to digital common (common screw on heat sink of VR901).	
CPU clock (U905 pins 38 and 39).	4MHz (TTL Level)
Check seating of all chips on the CPU board. Make sure each clip is secure in its socket. Updated software is presently at C-2.	To reduce troubleshooting time replace the CPU board if checks 1, 2 and 3 are present. If the checks are functional continue to isolator board checks paragaph 7.9.6. The problem is probably not with the CPU board.

Table 7-9. Isolator Board Checks

Condition	Remarks
5V power supply output VR801 referenced to digital common (common screw on heat sink of VR801).	If 5V is not present replace the isolator board.
Check the inputs (pin 3) and outputs (pin 6) of opto-isolators AT1-AT3. The inputs are referenced to digital common (Common screw on heat sink of VR801). The outputs are referenced to analog common (negative terminal of C816). The output of AT1 should look like Figure 7-12. The output of AT2 and AT3 should look like Figure 7-13.	Refer to Figures 7-12 and 7-13.
Check the input (pin 3) and output (pin 6) of opto-isolator AT4. The input is referenced to analog common. The output of AT4 should look like Figure 7-14.	Refer to Figure 7-14.

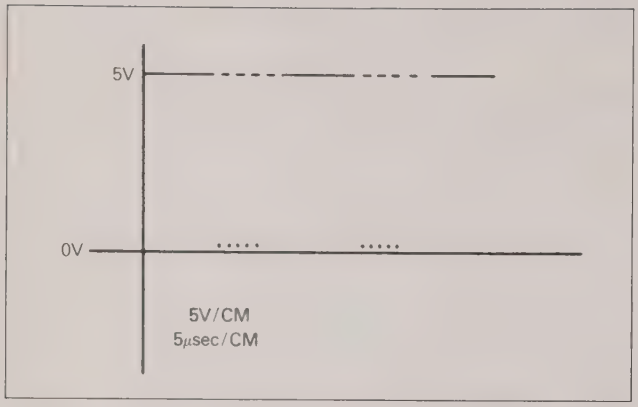


Figure 7-12. Output of AT1

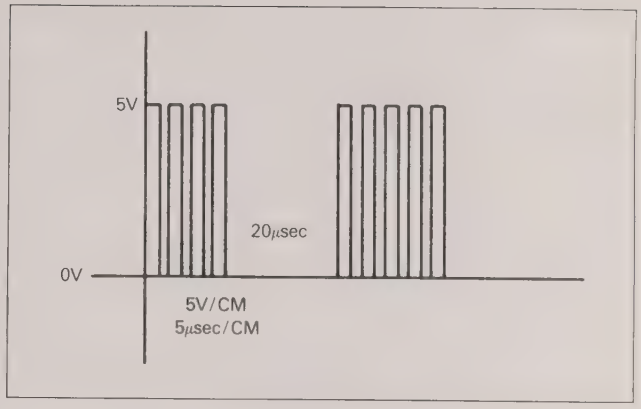


Figure 7-13. Output of AT2 and AT3

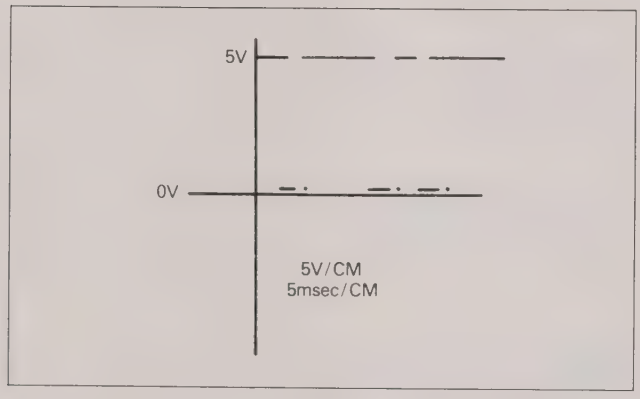


Figure 7-14. Output of AT4

7.9.7 Filter Mux Board Checks

The procedure for checking the filter mux board is listed in Table 7-10. If the filter mux board is replaced, 200mV and 2V calibration should be checked, as described in paragraph 7.5.

7.9.8 A/D Board Checks

Check the A/D board with the procedure in Table 7-11. The integrator waveform is shown in Figure 7-15.

Table 7-10. Filter Mux Board Checks

Condition	Remarks
U402 pin 1, referenced to analog common (U401 pin 4).	6.95 ±35mV reference voltage.
U401 pin 6, referenced to analog common (U401 pin 4).	10V reference, should be quiet and stable.
Check output of buffer for zero. [Emmitter of Q403, reference to bootstrap ground (pin 14 of R427)].	If the measurement is not zero, replace the filter mux board.

Table 7-11. Analog to Digital Converter Board (A/D) Checks

Condition	Remarks
Check operation of the transconductance amplifier (U501, VR501, Q501 and associate circuitry). The The reference voltage produced by VR501 is 6.4V ±5%. Pins 2 and 3 of U501 should be quiet.	If noise is intermittent, replace the A/D board and monitor the output for noise.
Check the noise level of the charge injector input. The charge injector consists of U514, Q505 and associated circuitry. A noisy display is often due to noise induced into the charge injector by a noisy or dirty R501 (TF-86).	Clean R501 with freon or replace the A/D board.
Check the output of integrator. The integrator consists of U507, Q503, C502 and associated circuitry. The output of the integrator should be stable and look like Figure 7-15.	Refer to Figure 7-15.

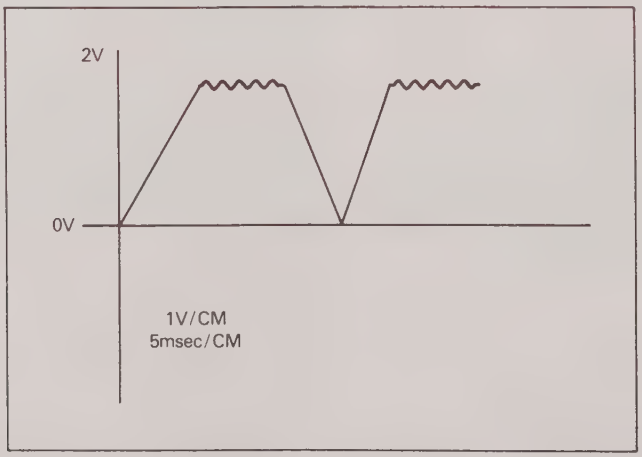


Figure 7-15. Integrator Output

7.9.9 Electrometer Board Checks

Use the procedure listed in Table 7-12 to check out the electrometer module. A self-test procedure for instruments equipped with two channels is included in step 3 and Table 7-13.

7.10 FAN FILTER CLEANING

The fan filter must be kept clean. Dirt in the filter will impede air flow through the instrument and cause overheating. To avoid this problem, the filter element should be periodically removed and cleaned with compressed air. Replacement elements may be obtained from Keithley Instruments; order part number FL-3.

Table 7-13. Analog Self Test

Ohms Range	Output Current
20 kΩ	100μA ± 0.5%
2MΩ	1μA ± 0.5%
200MΩ	10μA ± 0.5%
20GΩ	100pA ± 1.0%

Table 7-12. Electrometer Board Checks

Condition	Remarks
If the Model 619 is equipped with two electrometers (Channel A and Channel B), monitor both channels to verify both channels exhibit the same problem.	If only one channel is inoperative replace that channel.
If the Model 619 is not equipped with two electrometer channels, or if both channels are behaving identically, monitor the analog output of Channel A then Channel B as follows:	If analog output is not operating properly replace the electrometer.
Verify the analog output is zero with zero check engaged.	If analog output does not appear to have the same problem as observed on the front panel display, refer to filter mux board checks paragraph 7.9.7.
Verify the analog output follows the applied input voltage within the accuracy of that range.	
If the Model 619 is equipped with Channel A and Channel B electrometer, the user can perform an analog self test of the electrometers. The self test can be accomplished as follows:	
Connect the Channel A input to the Channel B input. Use a triax cable such as the Model 7024-3.	
Place Channel A in the ohm function and Channel B in the amps function.	
Step through Table 7-13 to perform the analog self test. The current source, provided by the channel in the ohms function, is measured by the channel in the amps function.	
Reverse the channels, that is, place Channel A in amps function and Channel B in the ohms function. Then repeat the previous step.	

SECTION 8
REPLACEABLE PARTS

8.1 INTRODUCTION

This section contains replacement parts information, component location drawings and schematic diagrams for the Model 619.

8.2 PARTS LIST

Parts are listed alphabetically in order of their circuit designations. Table 8-1 contains parts list information for the display board. Table 8-2 contains parts list information for the power supply. Table 8-3 contains IEEE-488 interface parts list information. Table 8-4 provides parts list information for the CPU board; while Table 8-5 contains parts list information for the isolator board. Parts list information for the A/D converter is presented in Table 8-6. Table 8-7 provides parts list for the electrometer modules. Table 8-8 contains parts list information for the filter mux board. Table 8-9 provides parts list information for the fan assembly. Table 8-10 list mechanical parts, which are also shown in Figure 7-11.

8.3 ORDERING INFORMATION

To place an order, or to obtain information concerning replacement parts, contact your Keithley representative or the factory. See the inside front cover for addresses. When ordering include the following information:

1. Instrument Model Number
2. Instrument Serial Number
3. Part Description
4. Circuit Designation (if applicable)
5. Keithley Part Number

8.4 FACTORY SERVICE

If the instrument is to be returned to the factory for service, please complete the service form which follows this section and return it with the instrument.

8.5 SCHEMATIC DIAGRAMS AND COMPONENT LOCATION DRAWINGS

Schematic diagrams and component location drawings follow the appropriate replaceable parts list for that particular board.

Table 8-1. Display Board, Parts List

Circuit Desig.	Description	Schematic Location	Keithley Part No.
C201	Capacitor, .1μF, 50V, Ceramic Film	B1	C-237-.1
C202	Capacitor, .1μF, 50V, Ceramic Film	B1	C-237-.1
C203	Capacitor, .1μF, 50V, Ceramic Film	B1	C-237-.1
C204	Capacitor, 33μF, 10V, Tantalum	A1	C-180-33
C205	Capacitor, .1μF, 50V, Ceramic Film	B1	C-237-.1
C207	Capacitor, .1μF, Ceramic Film	B1	C-237-.1
C208	Capacitor, 1000pF, Ceramic Disc	F4	C-64-1000p
DS201	Digital Display ±1	E1	DD-31
DS202	8 Segment Display	E1	DD-30
DS203	8 Segment Display	F1	DD-30
DS204	8 Segment Display	F1	DD-30
DS205	8 Segment Display	F1	DD-30
DS206	8 Segment Display	F1	DD-30
DS207	Digital Display ±1	G1	DD-31
DS208	8 Segment Display	G1	DD-30
DS209	LED, Red	F4	PL-67
DS210	LED, Red	F3	PL-67
DS211	LED, Red	F3	PL-67
DS212	LED, Red	H2	PL-67
DS213	LED, Red	F4	PL-67
DS214	LED, Red	G4	PL-67
DS215	LED, Red	H1	PL-67
DS216	LED, Red	F3	PL-67
DS217	LED, Red	G3	PL-67
DS218	LED, Red	H2	PL-67
DS219	LED, Red	F3	PL-67
DS220	LED, Red	G3	PL-67
DS221	LED, Red	H1	PL-67
DS222	LED, Red	F4	PL-67
DS223	LED, Red	G4	PL-67
DS224	LED, Red	F3	PL-67
DS225	LED, Red	G3	PL-67
DS226	LED, Red	F3	PL-67
DS227	LED, Red	G3	PL-67
DS228	LED, Red	G3	PL-67
DS229	LED, Red	H3	PL-67
LS201	Buzzer	F4	EM-3
R201	10kΩ, 5%, ¼W, Composition	C5	R-76-10k
R202	10kΩ, 5%, ¼W, Composition	D5	R-76-10k
R203	10kΩ, 5%, ¼W, Composition	D5	R-76-10k
R204	10kΩ, 5%, ¼W, Composition	E5	R-76-10k
R205	10kΩ, 5%, ¼W, Composition	F4	R-76-1.5M
R206	82Ω, 10%, ½W, Composition	D1	R-1-82
R207	82Ω, 10%, ½W, Composition	D1	R-1-82
R208	82Ω, 10%, ½W, Composition	C1	R-1-82
R209	82Ω, 10%, ½W, Composition	D1	R-1-82

Table 8-1. Display Board, Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
R210	82Ω, 10%, ½W, Composition	D1	R-1-82
R211	82Ω, 10%, ½W, Composition	E1	R-1-82
R212	82Ω, 10%, ½W, Composition	D1	R-1-82
R213	82Ω, 10%, ½W, Composition	D1	R-1-82
R214	82Ω, 10%, ½W, Composition	E3	R-1-82
R215	82Ω, 10%, ½W, Composition	E3	R-1-82
R216	82Ω, 10%, ½W, Composition	E3	R-1-82
R217	4.7k, 5%, ¼W, Composition	E3	R-76-4.7k
R218	4.7k, 5%, ¼W, Composition	E3	R-76-4.7k
R219	4.7k, 5%, ¼W, Composition	E3	R-76-4.7k
R220	68k, 5%, ¼W, Composition	E2	R-76-68k
S201	Switch, Pushbutton	C5	SW-435
S202	Switch, Pushbutton	D5	SW-435
S203	Switch, Pushbutton	D5	SW-435
S204	Switch, Pushbutton	E5	SW-435
S205	Switch, Pushbutton	C5	SW-435
S208	Switch, Pushbutton	E5	SW-435
S210	Switch, Pushbutton	D5	SW-435
S211	Switch, Pushbutton	E5	SW-435
S212	Switch, Pushbutton	E5	SW-435
S213	Switch, Pushbutton	C5	SW-435
S216	Switch, Pushbutton	E5	SW-435
S217	Switch, Pushbutton	C6	SW-435
S218	Switch, Pushbutton	D6	SW-435
S219	Switch, Pushbutton	D6	SW-435
S220	Switch, Pushbutton	E6	SW-435
S224	Switch, Pushbutton	E6	SW-435
U201	IC, Hex Inverter, 74LS05	Sev	IC-141
U202	IC, Hex Inverter, 4049	E4	IC-106
U203	IC, Darlington Array, ULN2003A	C3	IC-206
U204	IC, PIA, MC6821P	B2	LSI-8
U205	IC, Darlington Array, ULN2003A	C2	IC-206
U206	IC, Segment/Digit Driver, 75492	C2	IC-169
U207	IC, PIA, MC6821P	B4	LSI-8

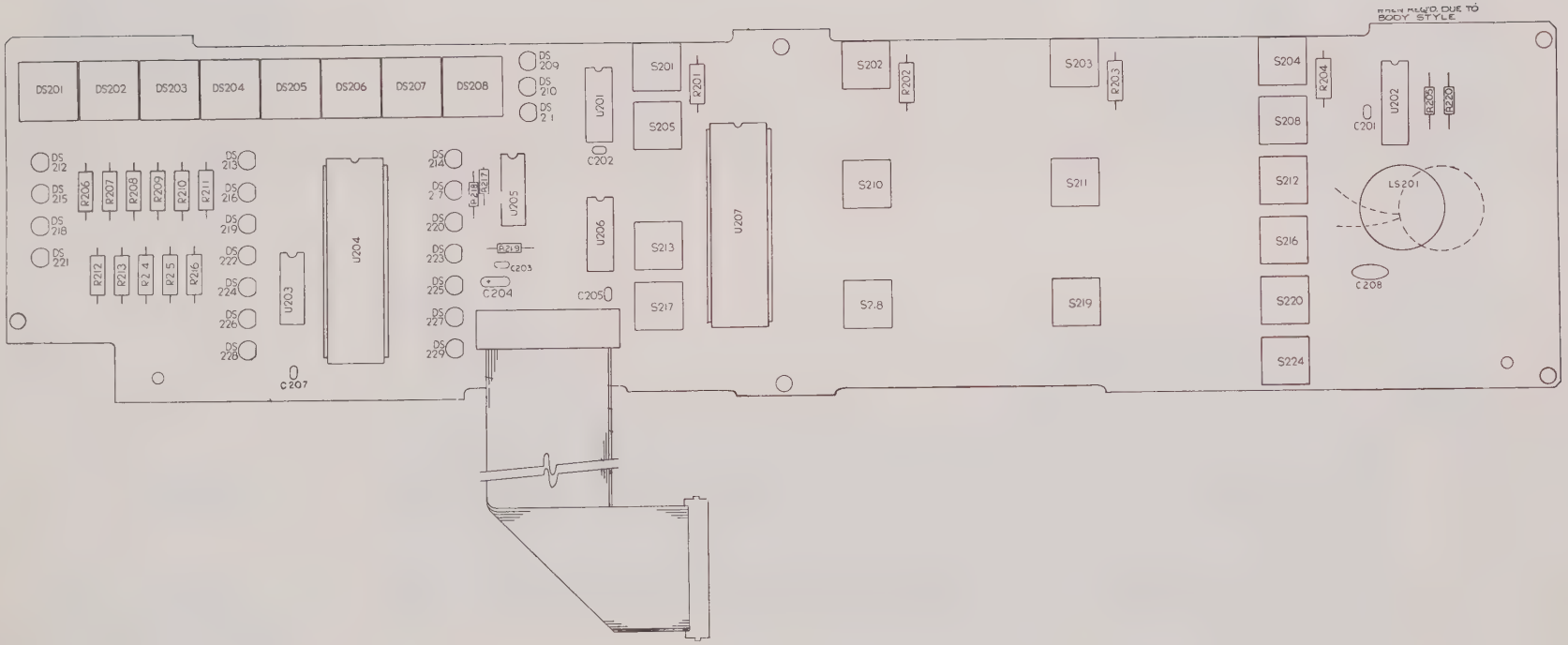


Figure 8-1. Display Board, Component Location Drawing, Drawing Number 32003

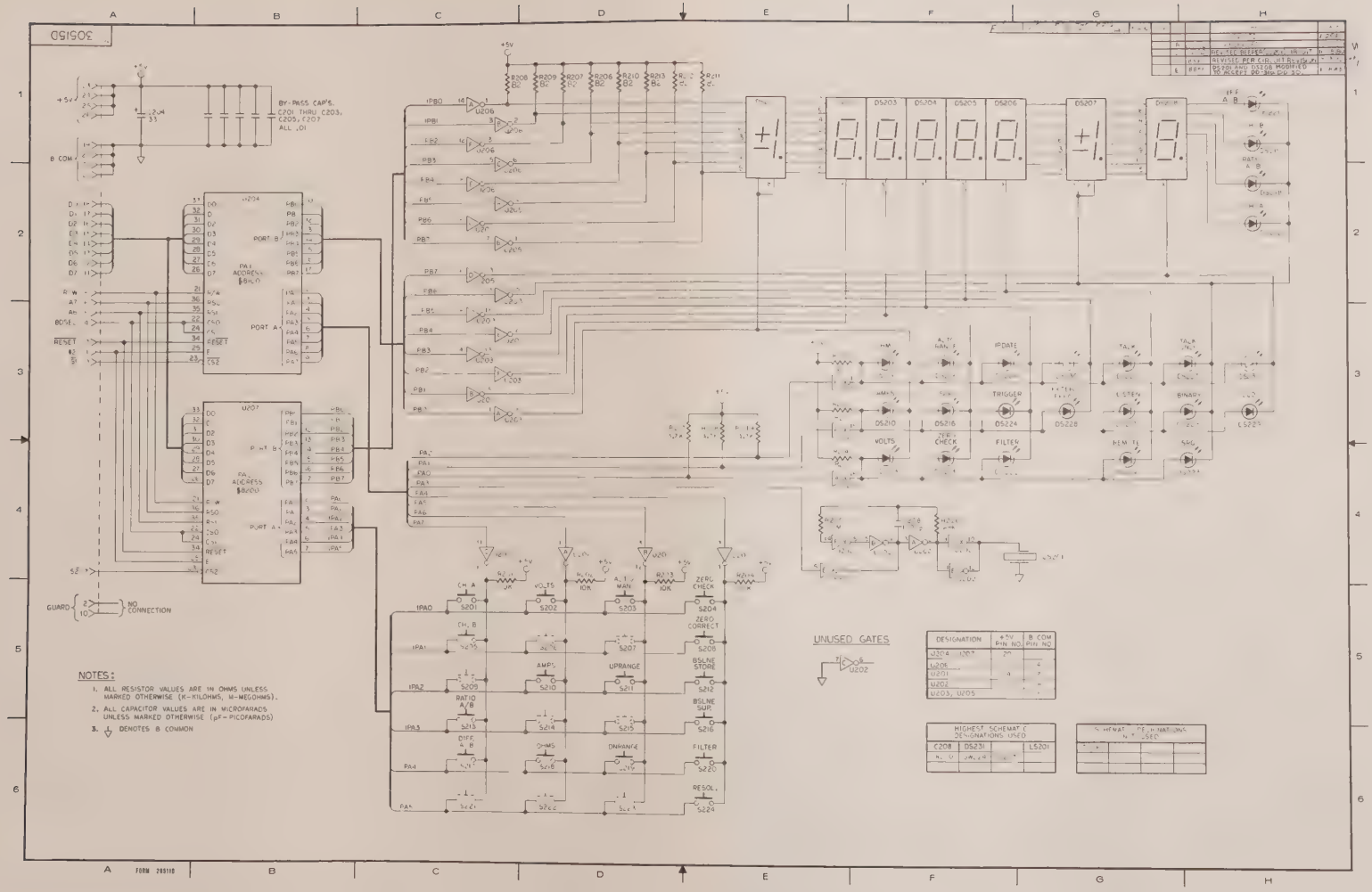

30515D
NOTES:
1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE (K=KILOHMS, M=MEGOHMS).
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE (pF=PICOFARADS)
3. ⏚ DENOTES B COMMON
UNUSED GATES
FORM 28518

Figure 8-2. Display Board, Schematic Diagram, Drawing Number 30515

Table 8-2. Power Supply, Parts List

Circuit Desig.	Description	Schematic Location	Keithley Part No.
C301	Capacitor, .01μF, 500V, Ceramic Disc	D5	C-22-.01
C302	Capacitor, 10,000μF, 25V, Aluminum Electrolytic	E4	C-342-10,000
C303	Capacitor, 10,000μF, 25V, Aluminum Electrolytic	E4	C-342-10,000
C304	Capacitor, 10μF, 25V, Aluminum Electrolyitc	E3	C-314-10
C305	Capacitor, 10μF, 35V, Electrolytci	E3	C-309-10
C306	Capacitor, 10μF, 25V, Aluminum Electrolytic	E2	C-314-10
C307	Capacitor, 10μF, 35V, Electrolyitc	E2	C-309-10
C308	Capacitor, 620μF, 35V, Electrolyitc	E3	C-309-620
C309	Capacitor, 620μF, 35V, Electrolyitc	E2	C-309-620
C310	Capacitor, 6800μF, 25V, Aluminum Electrolytic	E4	C-314-6800
C311	Capacitor, 10μF, 25V, Aluminum Electrolytic	E4	C-314-10
C312	Capacitor, 10μF, 25V, Aluminum Electrolytic	E4	C-314-10
CR301	Rectifier, Bridge, 6A, VH048	D4	RF-51
CR302	Rectifier, 5A, PE05	D4	RF-48
CR303	Rectifier, 1.5A, 400PIV, PF40	D2	RF-46
F301	Slow Blow, 250V, 1A/3AG	B3	FU-p10
F301	SLow Blow, 250V, ½A/3AG	B3	FU-4
J302	Connector Housing	C5	CS-287-3
J303	Connector Housing	B2	CS-287-3
J304	Connector	F4,5	CS-332-12
J305	Connector	F2,3	CS-332-12
J306	Connector		CS-249
J307	Connector		CS-249
P301	Filter, Power Line	A3	LF-2
P302	Connector	C5	CS-288-3
P303	Connector	B2	CS-288-3
R301	220k, 10%, 1W, Composition	D5	R-2-220k
R302	1k, 10%, ½W, Composition	E4	R-1-1k
R303	4.7k, 5%, ¼W, Composition	E3	R-76-4.7k
R304	470, 10%, ½W, Composition	E4	R-1-470
R305	4.7k, 5%, ¼W, Composition	E2	R-76-4.7k
S301	Switch DPDT	C2	SW-397
S302	Switch DPDT	C3	SW-397
S303	Switch DPDT	B2	SW-236
S304	Switch, Power	B1	SW-420
T301	Transformer	Sec	TR-175
VR301	Voltage Regulator, −15V, MC7915CT	E3	IC-174
VR302	Voltage Regulator, +15V, MC7815CT	E2	IC-96
VR303	Voltage Regulator, +5V, MLM109KA	E3	IC-98

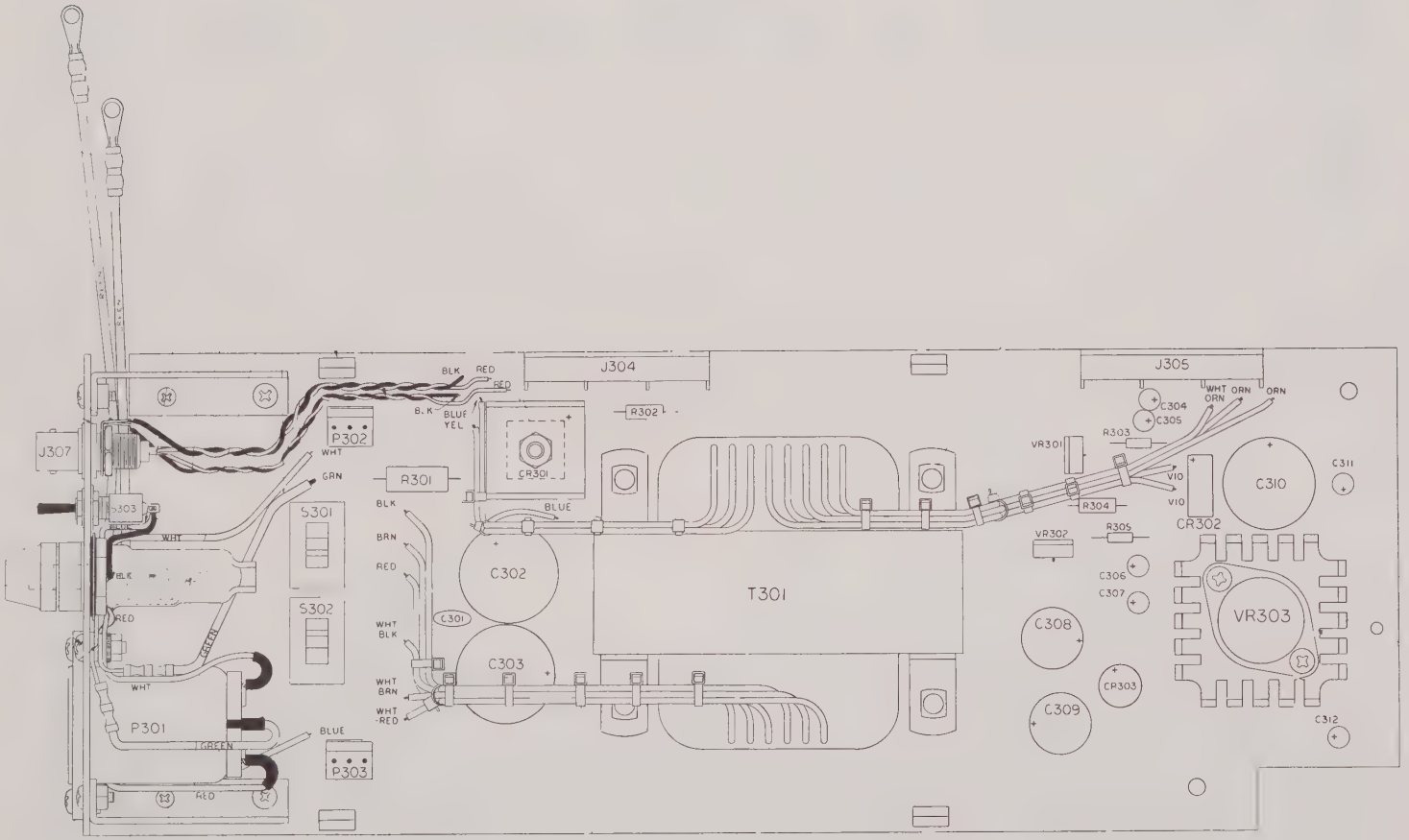


Figure 8-3. Power Supply Board, Component Location Drawing, Drawing Number 32004

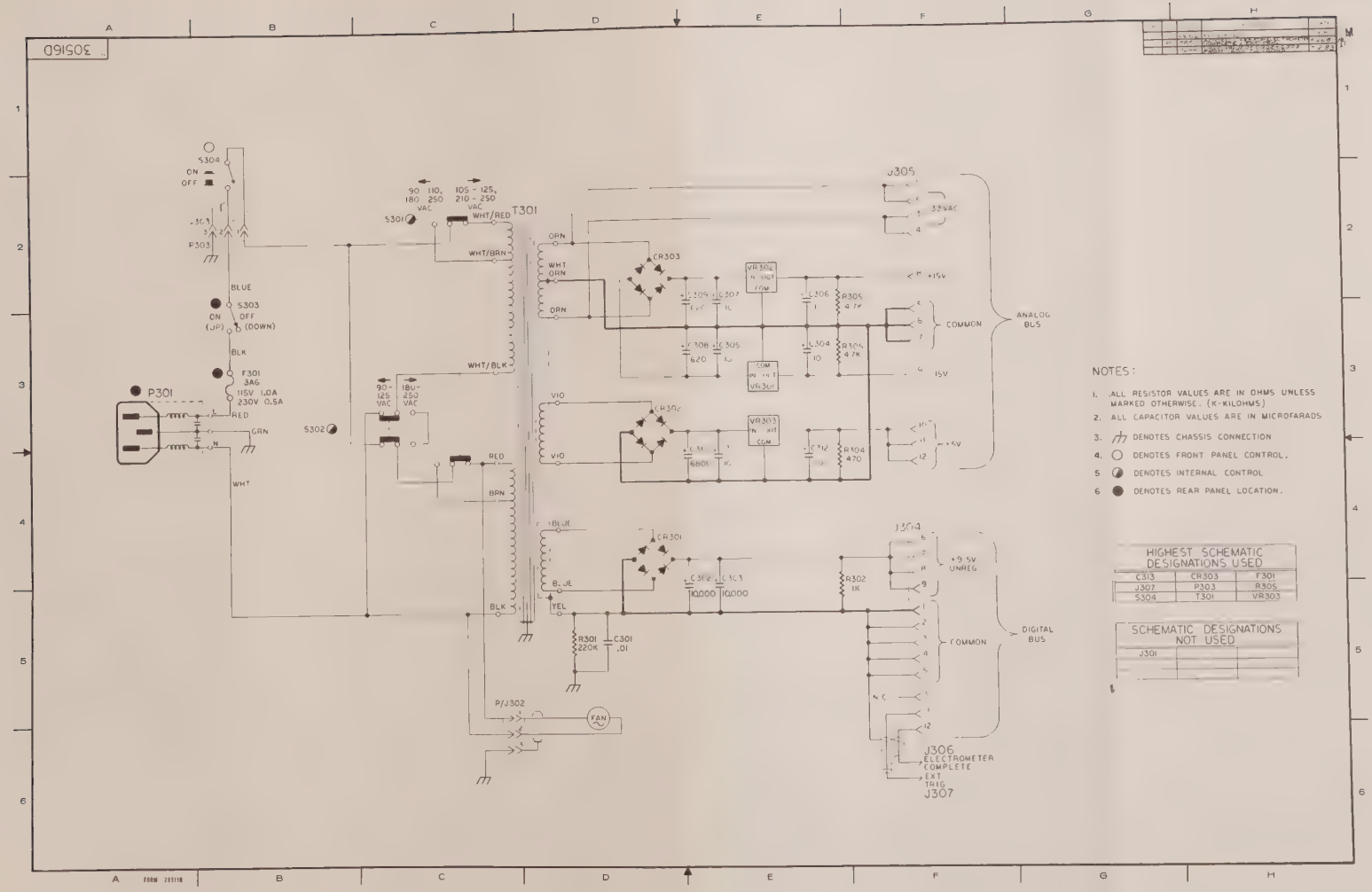


Figure 8-4. Power Supply Board, Schematic Diagram, Drawing Number 30516

Table 8-3. IEEE Interface, Parts List

Circuit Desig.	Description	Schematic Location	Keithley Part No.
C701	Capacitor, .1μF, 16V, Ceramic Disc		C-238-.1
C702	Capacitor, .1μF, 16V, Ceramic Disc	A1	C-238-.1
C703	Capacitor, .1μF, 16V, Ceramic Disc	B1	C-238-.1
C704	Capacitor, .1μF, 16V, Ceramic Disc	B1	C-238-.1
C705	Capacitor, .1μF, 16V, Ceramic Disc	B1	C-238-.1
C706	Capacitor, .1μF, 16V, Ceramic Disc	B1	C-238-.1
C707	Capacitor, .1μF, 16V, Ceramic Disc	B1	C-238-.1
C708	Capacitor, .1μF, 16V, Ceramic Disc	C1	C-238-.1
C709	Capacitor, .1μF, 16V, Ceramic Disc	C1	C-238-.1
C710	Capacitor, .1μF, 16V, Ceramic Disc	C1	C-238-.1
C711	Capacitor, .1μF, 16V, Ceramic DIsc	C1	C-238-.1
C712	Capacitor, 10μF, 25V, Aluminum Electrolytic	B6	C-314-10
C713	Capacitor, 22μF, 25V, Aluminum Electrolytic	B6	C-314-22
J701	IEEE-488 Connector	Sev	CS-377
R701	Resistor, Thick Film	D1	TF-100
R702	Resistor, 3.3kΩ, 5%, ¼W, Composition		
TP1	Test Point	D5	CS-339-4
TP2	Test Point	B4	CS-339-4
TP3	Test Point	B4	CS-339-4
TP4	Test Point		CS-339-4
U701	IC, Bus Transceiver, MC3448A	F5	IC-193
U702	IC, Bus Transceiver, MC3448A	F2	IC-193
U703	IC, Buffer/Line Driver, 74LS244	B5	IC-230
U704	IC, Bus Transceiver, MC3448A	F4	IC-193
U705	IC, Bus Transceiver, MC3448A	F3	IC-193
U706	IC, GPIA, 68488	E3	LSI-14
U707	IC, Hex Inverter, 74LS04	Sev	IC-186
U708	IC, Triple-3 Input NAND Gate	Sev	IC-155
U709	IC, Hex-3 State Buffer, 74LS367	D2	IC-161
U710	IC, Quad Bus Receiver, 8T26	B4	IC-180
U711	IC, Quad Bus Receiver, 8T26	B2	IC-180
VR701	Regulator, 5V, MC7805	B6	IC-93

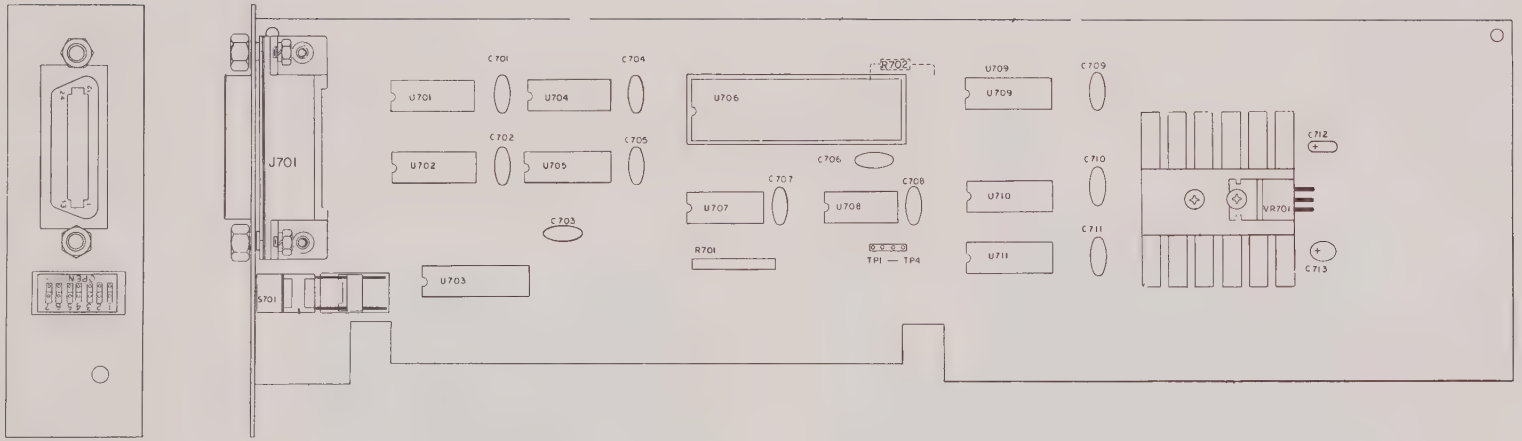


Figure 8-5. IEEE Interface Board, Component Location Drawing, Drawing Number 30329

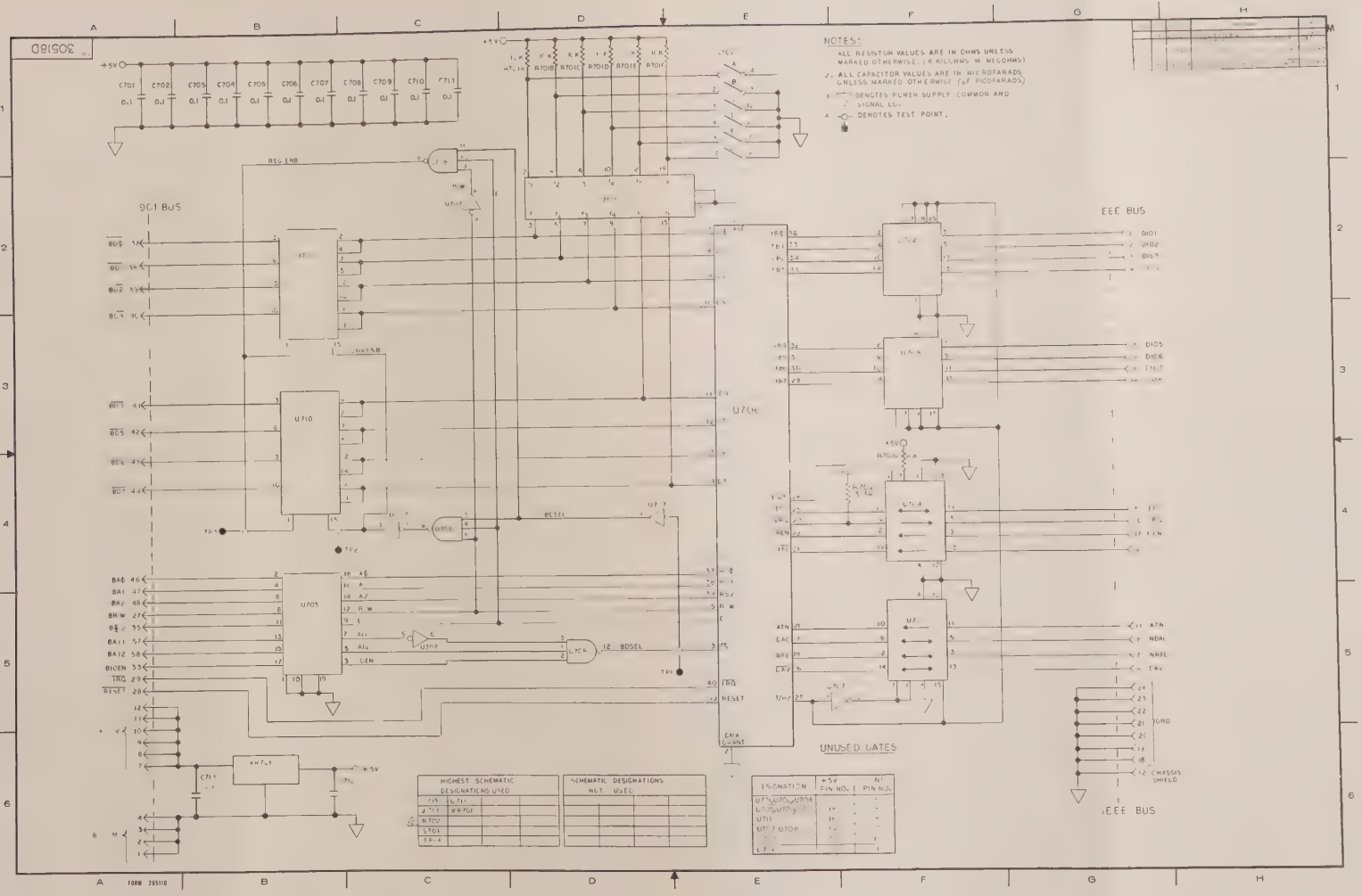


Figure 8-6. IEEE Interface Board, Schematic Diagram, Drawing Number 30518

Table 8-4. CPU Board, Parts List

Circuit Desig.	Description	Schematic Location	Keithley Part No.
C901	Capacitor, .1μF, 50V, Ceramic Film	B5	C-237-.1
C902	Capacitor, .1μF, 50V, Ceramic Film	B5	C-237-.1
C903	Capacitor, .1μF, 50V, Ceramic Film	B5	C-237-.1
C904	Capacitor, .1μF, 50V, Ceramic Film	B5	C-237-.1
C905	Capacitor, .1μF, 50V, Ceramic Film	B5	C-237-.1
C906	Capacitor, .1μF, 50V, Ceramic Film	B5	C-237-.1
C907	Capacitor, .1μF, 50V, Ceramic Film	B5	C-237-.1
C908	Capacitor, .1μF, 50V, Ceramic Film	B5	C-237-.1
C909	Capacitor, .1μF, 50V, Ceramic Film	B5	C-237-.1
C910	Capacitor, 22pF, 1000V, Ceramic Disc	D2	C-64-22pF
C911	Capacitor, 22pF, 1000V, Ceramic Disc	D2	C-64-22pF
C912	Capacitor, .1μF, 50V, Ceramic Film	D2	C-237-.1
C913	Capacitor, .1μF, 50V, Ceramic Film	C5	C-237-.1
C914	Capacitor, .1μF, 16V, Ceramic Disc	D2	C-238-.1
C915	Capacitor, .01μF, 16V, Ceramic Disc	E2	C-238-.01
C916	Capacitor, .1μF, 16V, Ceramic Disc	E2	C-238-.1
C917	Capacitor, .1μF, 50V, Ceramic Film	C5	C-237-.1
C918	Capacitor, 22μF, 25V, Aluminum Electrolytic	A5	C-314-22
C919	Capacitor, .1μF, 50V, Ceramic Film	C5	C-237-.1
C920	Capacitor, .1μF, 50V, Ceramic Film	C5	C-237-.1
C921	Capacitor, .1μF, 50V, Ceramic Film	C5	C-237-.1
C922	Capacitor, .1μF, 50V, Ceramic Film	C5	C-237-.1
C923	Capacitor, 10μF, 25V, Aluminum Electrolyitc	C5	C-237-.1
C924	Capacitor, .1μF, 50V, Ceramic Film	C5	C-237-.1
CR901	Diode, Silicon, 1N914	E1	RF-28
R901	Resistor, Thick Film		TF-101
R902	Resistor, 1MΩ, 5%, ¼W, Composition	E1	R-76-1M
R903	Resistor, 1MΩ, 5%, ¼W, Composition	E2	R-76-1.5M
U901	IC, Buffer/Line Driver, 74LS244	C4	IC-230
U902	IC, Dual 4 Input NAND, 74LS20	B3,4	IC-232
U903	IC, Dual 4 Input NAND, 74LS20	D5,6	IC-232
U904	IC, Triple-3 Input NOR, 74LS27	D4,6	IC-233
U905	IC, Microprocessor with clock, MC6808	Sev	LSI-27
U906	IC, Prom	F4	PRO-114*
U907	Not USed		
U908	IC, Buffer/Line Driver, 74LS244	C3	IC-230
U909	IC, Hex Inverter, 74LS04	Sev	IC-186
U910	IC, Triple-3 Input NAND, 74LS14	D5	IC-155
U911	IC, Hex-3 State Buffer, 74LS367	C5	IC-161
U912	IC, Quad-2 Input NAND, 74LS00	Sev	IC-163
U913	IC, Programmable Module Timer, 6840	B2,3	LSI-26
U914	IC, Decoder/Multiplexer, 74LS139	D4	IC-190
U915	PROM	F3	PRO-115*
U916	IC, Quad-2 Input NAND, 74LS03	Sev	IC-231

Table 8-4. CPU Board, Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
U917	IC, Timing Circuit, NE555	E2	IC-71
U918	IC, Quad Bus Receiver, 8T26	C2	IC-180
U919	IC, Static RAM, 2114L	E2	LSI-15
U920	Static RAM, 2114L	E1	LSI-15
U921	Quad Bus Receiver, 8T26	C1	IC-180
U922	Static RAM, 2114L	F2	LSI-15
U923	Static RAM, 2114L	F1	LSI-15
VR901	5V Regulator, MC7805	B5	IC-93
Y901	4MHz Crystal	D2	CR-10
TP1	Test Point	E5	CS-339-4
TP2	Test Point	E5	CS-339-4
TP3	Test Point	E5	CS-339-4
TP4	Test Point	F5	CS-339-4
TP5	Test Point	E5	24249A
TP6	Test Point	C6	CS-339-2
TP7	Test Point	C6	CS-339-2
TP8	Test Point	B5	CS-339-2
TP9	Test Point	B5	CS-339-2
TP10	Test Point	A2	CS-339-3
TP11	Test Point	B1	CS-339-3
TP12	Test Point	B2	CS-339-3
W901	Jumper	G4	J-3
W902	Jumper	D5	J-3
W903	Jumper	D6	J-3
W904	Jumper	D5	J-3
W905	Not Used		
W906	Not Used		
W907	Not Used		
W908	Jumper	B5	J-3

*Order same as current software level displayed on power-up. For example, if C2 is displayed, order PRO-114-C2.

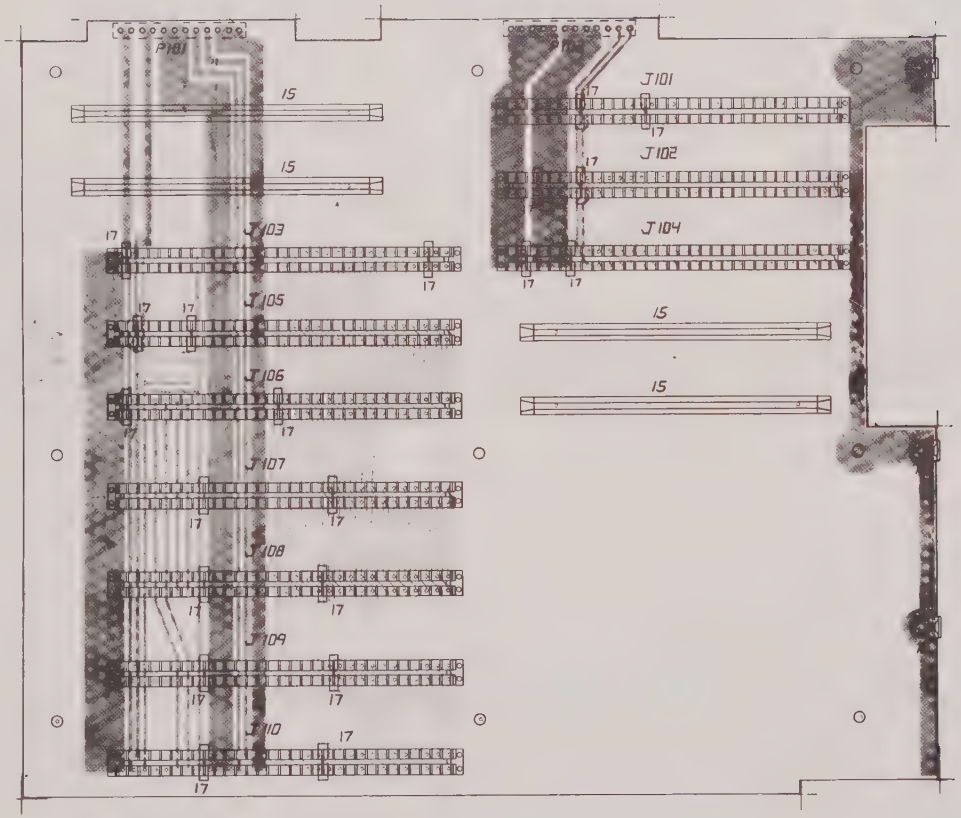


Figure 8-7. Mother Board, Component Location Drawing, Drawing Number 30411

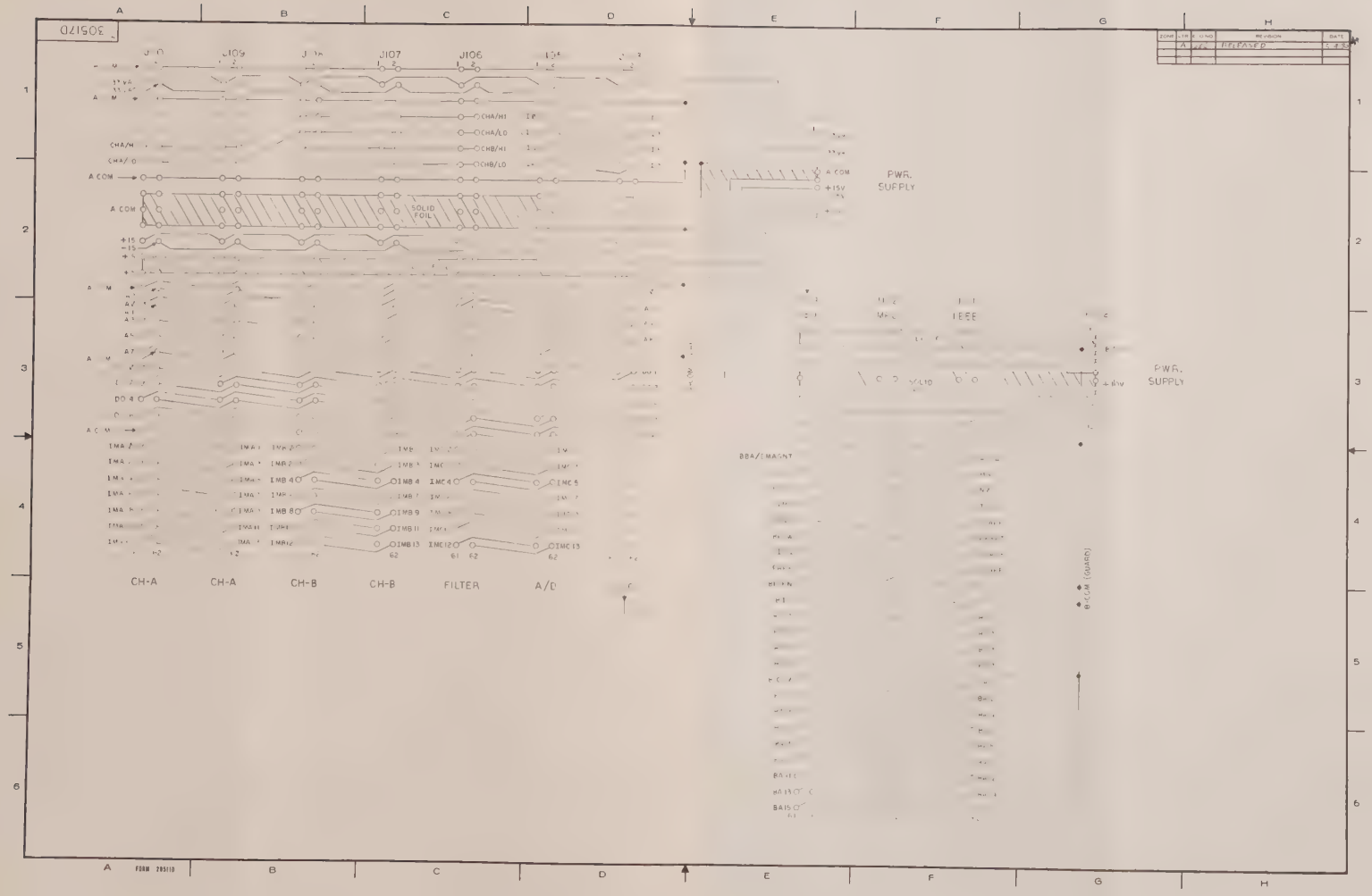


Figure 8-8. Mother Board, Schematic Diagram, Drawing Number 30517

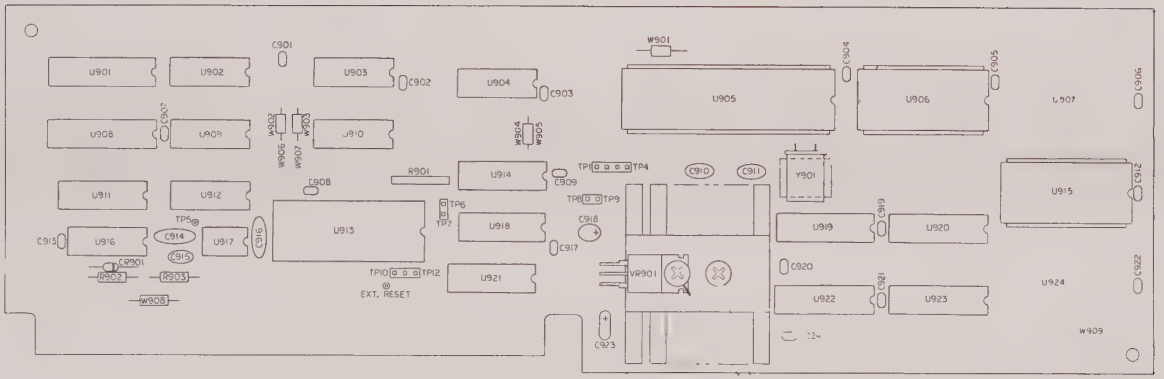


Figure 8-9. Processor Board, Component Location Drawing, Drawing Number 32005

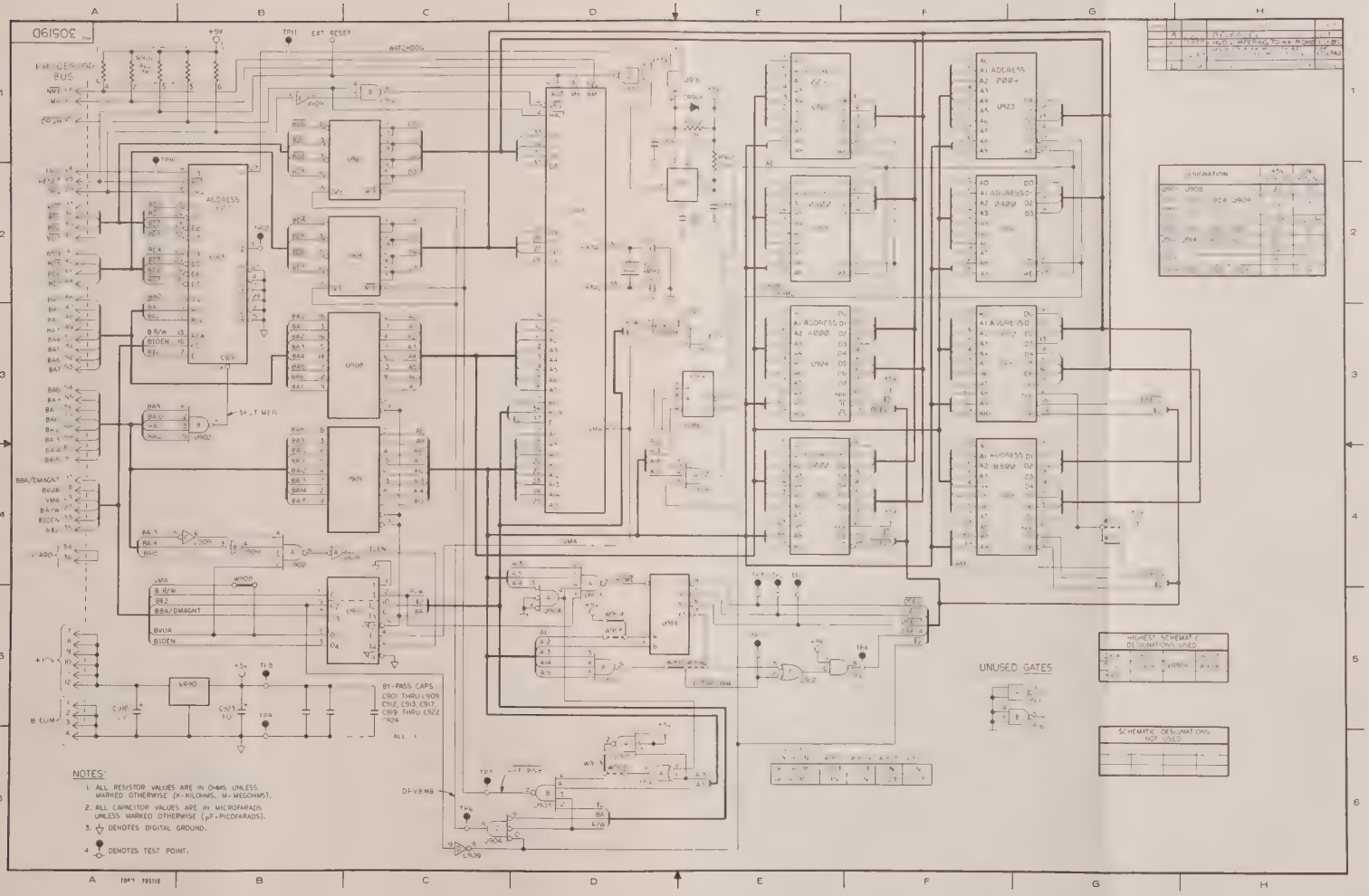


Figure 8-10. Processor Board, Schematic Diagram, Drawing Number 30519

Table 8-5. Isolator Board, Parts List

Circuit Desig.	Description	Schematic Location	Keithley Part No.
AT1	Opto Coupler, HCPL-2601	E5	IC-239
AT2	Opto Coupler, HCPL-2601	E4	IC-239
AT3	Opto Coupler, HCPL-2601	E3	IC-239
AT4	Opto Coupler, HCPL-2601	E1	IC-239
C801	Capacitor, .1μF, 50V, Ceramic Film	B1	C-237-.1
C802	Capacitor, .1μF, 50V, Ceramci Film	B1	C-237-.1
C803	Capacitor, .1μF, 50V, Ceramic Film	B1	C-237-.1
C804	Capacitor, .1μF, 50V, Ceramic Film	B1	C-237-.1
C805	Capacitor, .1μF, 50V, Ceramic Film	B1	C-237-.1
C806	Capacitor, .1μF, 50V, Ceramic Film	B1	C-237-.1
C807	Capacitor, 10μF, 25V, Aluminum Electrolytic	B1	C-314-10
C808	Capacitor, 22μF, 25V, Aluminum Electrolytic	A1	C-314-22
C809	Capacitor, .1μF, 50V, Ceramic Film	G5	C-237-.1
C810	Capacitor, .1μF, 50V, Ceramic Film	G5	C -237-.1
C811	Capacitor, .1μF, 50V, Ceramic Film	G5	C-237-.1
C812	Capacitor, .1μF, 50V, Ceramic Film	G5	C-237-.1
C813	Capacitor, .1μF, 16V, Ceramic Disc	E5	C-238-.1
C814	Capacitor, .1μF, 16V, Ceramic Disc	E4	C-238-.1
C815	Capacitor, .1μF, 16V, Ceramic Disc	E3	C-238-.1
C816	Capacitor, 22μF, 25V, Aluminum Electrolytic	G5	C-314-22
C817	Capacitor, .1μF, 50V, Ceramic Film	G5	C-237-.1
C818	Capacitor, .1μF, 16V, Ceramic Disc	E2	C-238-.1
C819	Capacitor, .1μF, 50V, Ceramic Film	B1	C-237-.1
CR801	Rectifier, 1N914	A6	RF-28
CR802	Rectifier, 1N914	A6	RF-28
CR803	Rectifier, 1N914	A6	RF-28
CR804	Rectifier, 1N914	A6	RF-28
P801	Connector	A	CS-322-27
R801	Resistor, Thick Film	D4	TF-100
R802	Resistor, 270Ω, 5%, ¼W, Composition	E3	R-76-270
R803	Resistor, 270Ω, 5%, ¼W, Composition	E2	R-76-70
R804	Resistor, 270Ω, 5%, ¼W, Composition	E4	R-76-270
R805	Resistor, 390Ω, 5%, ¼W, Composition	D1	R-76-390
R806	Resistor, 390Ω, 5%, ¼W, Composition	E4	R-76-390
R807	Resistor, 390Ω, 5%, ¼W, Composition	E3	R-76-390
R808	Resistor, 10kΩ, 5%, ¼W, Composition	F1	R-76-10k
R809	Resistor, 390Ω, 5%, ¼W, Composition	E2	R-76-390
R810	Resistor, 270Ω, 5%, ¼W, Composition	E1	R-76-270
S801	Switch	D3	SW-422
U801	IC, Hex Inverter, 74LS04	Sev	IC-186
U802	IC, Decoder/Multiplexer, 74LS139	A5	IC-190
U803	IC, Buffer/Line Driver, 74LS244	A4	IC-230

Table 8-5. Isolator Board, Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
U804	IC, Triple-3 Inpt NAND, 74LS10	Sev	IC-155
U805	IC, Quad Bus Receiver, 8T26	A2	IC-180
U806	IC, Quad Bus Receiver, 8T26	A3	IC-180
U807	IC, Versatile Interface Adapter, 6522	D	LSI-28
U808	IC, Shift Register, 74LS164	D2	IC-127
U809	IC, Quad-2 Input NAND, 7400	Sev	IC-38
U810	IC, Quad-2 Input NOR, 74LS02	Sev	IC-179
U811	IC, Odd/Even Parity Generator Checker, 74LS280	F3	IC-236
U812	IC, Shift Register, 74LS164	F3	IC-127
U813	IC, Quad-2 Input NAND, 7400	Sev	IC-38
U814	IC, Odd/Even Parity Generator Checker, 74LS280	F4	IC-236
U815	IC, Shift Register, 74LS164	F2	IC-127
U816	C, 8-Bit Parallel Serial Conv., 74LS165	F1	IC-237
VR801	5V Regulator, SH323SC	D2	IC-240

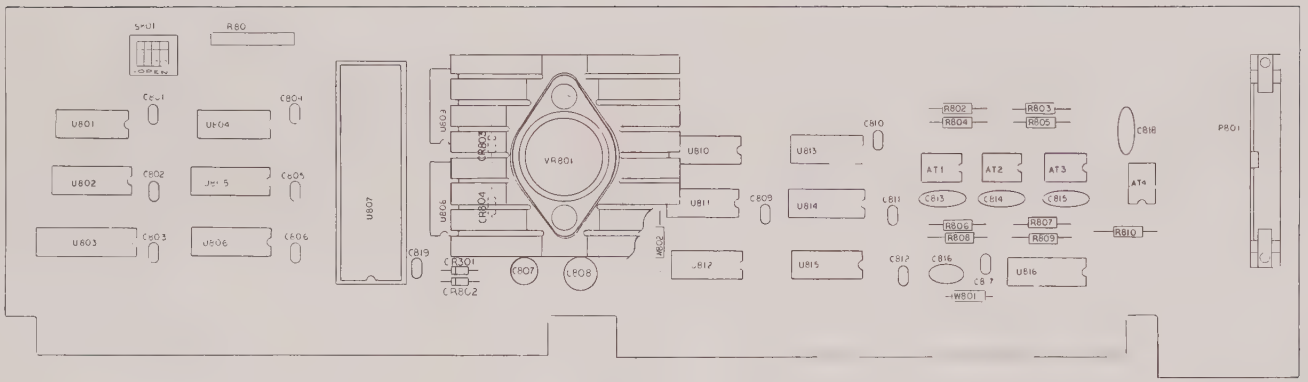


Figure 8-11. Isolator Board, Component Location Drawing, Drawing Number 32006

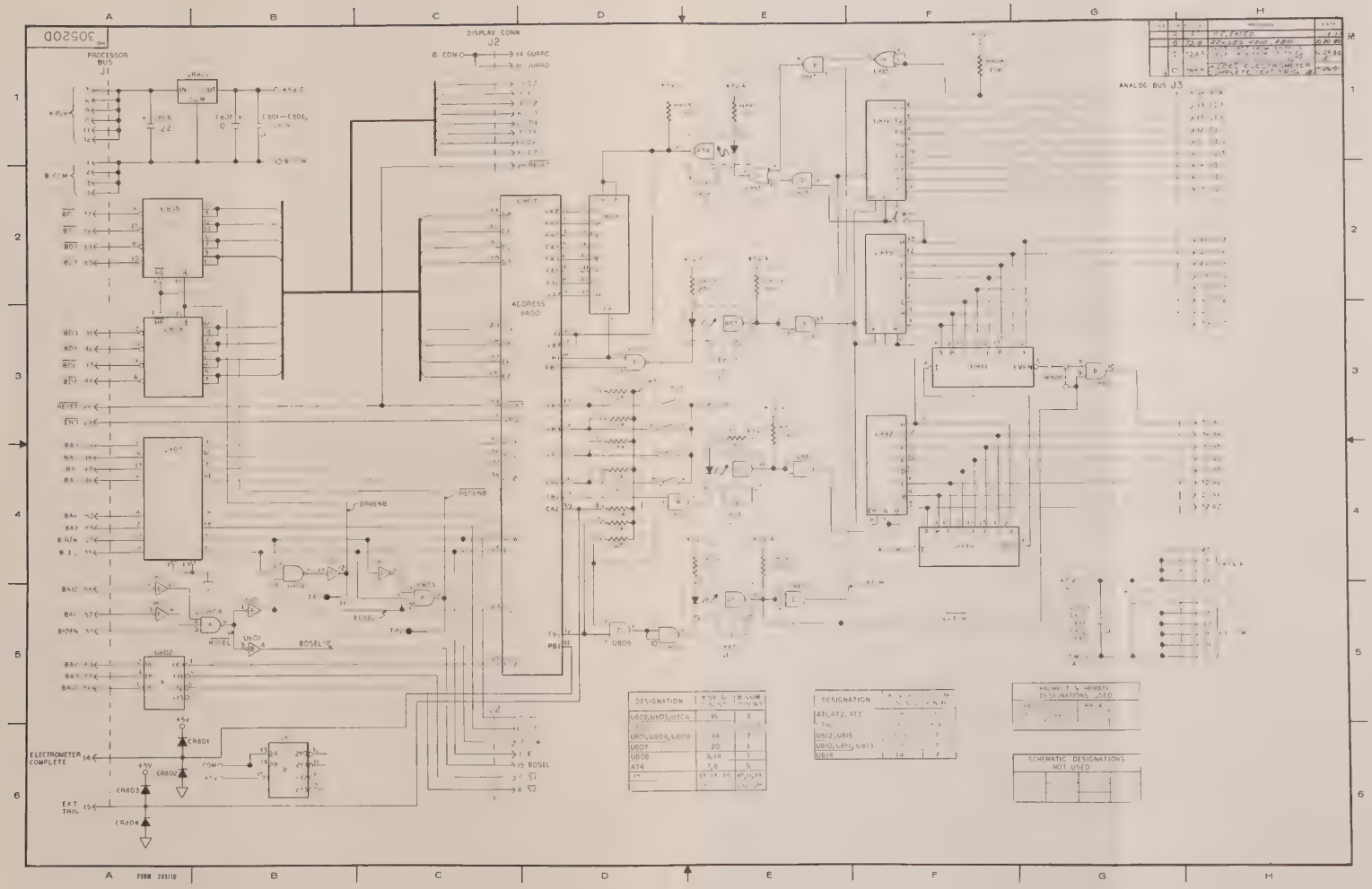


Figure 8-12. Isolator Board, Schematic Diagram, Drawing Number 30520

Table 8-6. A/D Converter, Parts List

Circuit Desig.	Description	Schematic Location	Keithley Part No.
C501	Capacitor, .1μF, 16V, Ceramic Disc	H5	C-238-.1
C502	Capacitor, 3600pF, 1000V, Ceramic Disc	A3	C-138-3600pF
C503	Capacitor, .1μF, 16V, Ceramic Disc	H5	C-238-.1
C504	Capacitor, .1μF, 16V, Ceramic Disc	H5	C-238-.1
C505	Capacitor, .1μF, 16V, Ceramic Disc	H5	C-238-.1
C506	Capacitor, .1μF, 16V, Ceramic Disc	F1	C-238-.1
C507	Capacitor, 100pF, 1000V, Ceramic Disc	G1	C-64-100pF
C508	Capacitor, .1μF, 16V, Ceramic Disc	G1	C-238-.1
C509	Capacitor, 100pF, 1000V, Ceramic Disc	F2	C-64-100pF
C510	Capacitor, .1μF, 16V, Ceramic Disc	E1	C-238-.1
C511	Capacitor, .1μF, 16V, Ceramic Disc	H5	C-238-.1
C512	Capacitor, .1μF, 50V, Ceramic Film	H5	C-237-.1
C513	Capacitor, .1μF, 50V, Ceramic Film	H5	C-237-.1
C514	Capacitor, .1μF, 16V, Ceramic Disc	H5	C-238-.1
L501	Choke	F1	CH-14
Q501	Transistor, N-Channel J-FET	B6	TG-77
Q502	Transistor Array, Selected	A4	29198A
Q503	Transistor NPN, 2N3904	A3	TG-47
Q504	Transistor PNP, 2N3906	A2	TG-84
Q505	Transistor PNP, 2N3906	B1	TG-84
Q506	Transistor PNP, 2N3906	C1	TG-84
Q507	Transistor Array, Selected	C1	29198A
Q508	Transistor N-Channel J-FET, Selected	G1	TG-77
Q509	Transistor NPN, 2N3904	B6	TG-47
Q510	Transistor PNP, 2N3906	B2	TG-84
R501	Resistor, Thick Film	Sev	TF-86
R502	Resistor, Thick Film	Sev	TF-85
R503	Resistor, 6.8MΩ, 10%, ¼W, Composition	B5	R-76-6.8M
R504	Resistor, 4.99Ω, 1%, 1/8W	B6	R-88-4.99k
R505	Resistor, 330Ω, 5%, ¼W, Composition	F2	R-76-330
R506	Resistor, 330Ω, 5%, ¼W, Composition	F1	R-76-330
R507	Resistor, 22Ω, 5%, ¼W, Composition	G1	R-76-22
R508	Resistor, 10MΩ, 10%, ¼W, Composition	F2	R-76-10M
R509	Resistor, 6.8Ω, 5%, ¼W, Composition	E1	R-76-6.8
R510	Resistor, 10kΩ, 5%, ¼W, Composition	C6	R-76-10k
U501	IC, Bi-FET Op Amp, LF351	A6	IC-176
U502	IC, Triple-3 Input NAND, 74LS10	D3	IC-155
U503	IC, Flip-Flop, 74LS74	E3	IC-144
U504	IC, Triple-3 Input NAND, 74LS10	B5	IC-155
U505	IC, Decade and Binary Counter, 74LS393	F4	IC-213
U506	IC, Flip-Flop, 74LS74	B3	IC-216
U507	IC, Bi-FET Op Amp, LF351N	A3	IC-176
U508	IC, Quad 2-Input NAND, 74LS00	Sev	IC-163

Table 8-6. A/D Converter, Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
U509	IC, Up Down Counter, 74LS193	F5	IC-214
U510	IC, Up Down Counter, 74LS193	G5	IC-214
U511	IC, Decade and Binary Counter, 74LS393	D4	IC-213
U512	IC, Buffer/Line Driver,	E6	IC-230
U513	IC, Quad 2-Input NOR, 74LS02	Sev	IC-179
U514	IC, Bi Fet Op Amp, LF351N	B1	IC-176
U515	IC, Voltage Comparator, LM311N	C2	IC-173
U516	IC, Up Down Counter, 74193	F1	IC-44
U517	IC, Flip-Flop, 74LS374	E6	IC-242
U518	IC, Decade and Binary Counter, 74LS393	D4	IC-213
U519	IC, Buffer/Line Driver, 74LS244	D5	IC-230
VR501	Zener Diode, 6.4V, 1N4571	A6	DZ-60
Y501	Crystal, 4.9152MHz	F1	CR-12

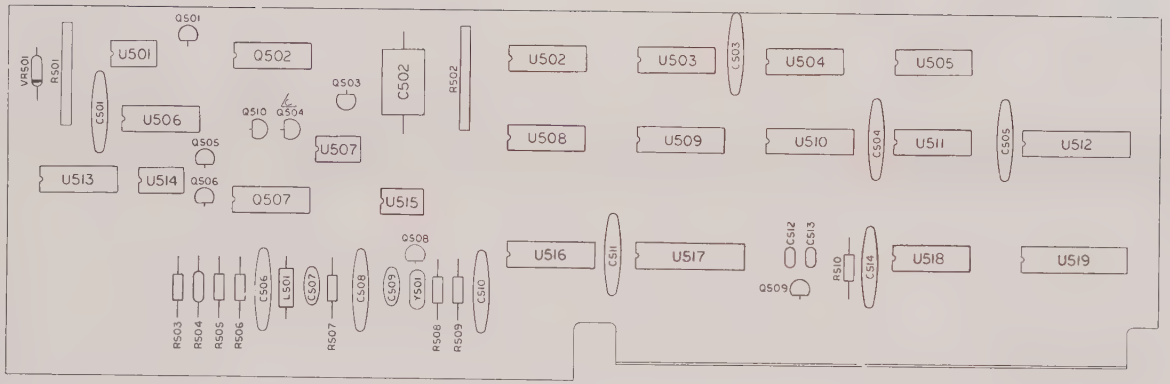


Figure 8-13. A/D Converter Board, Component Location Drawing, Drawing Number 30395

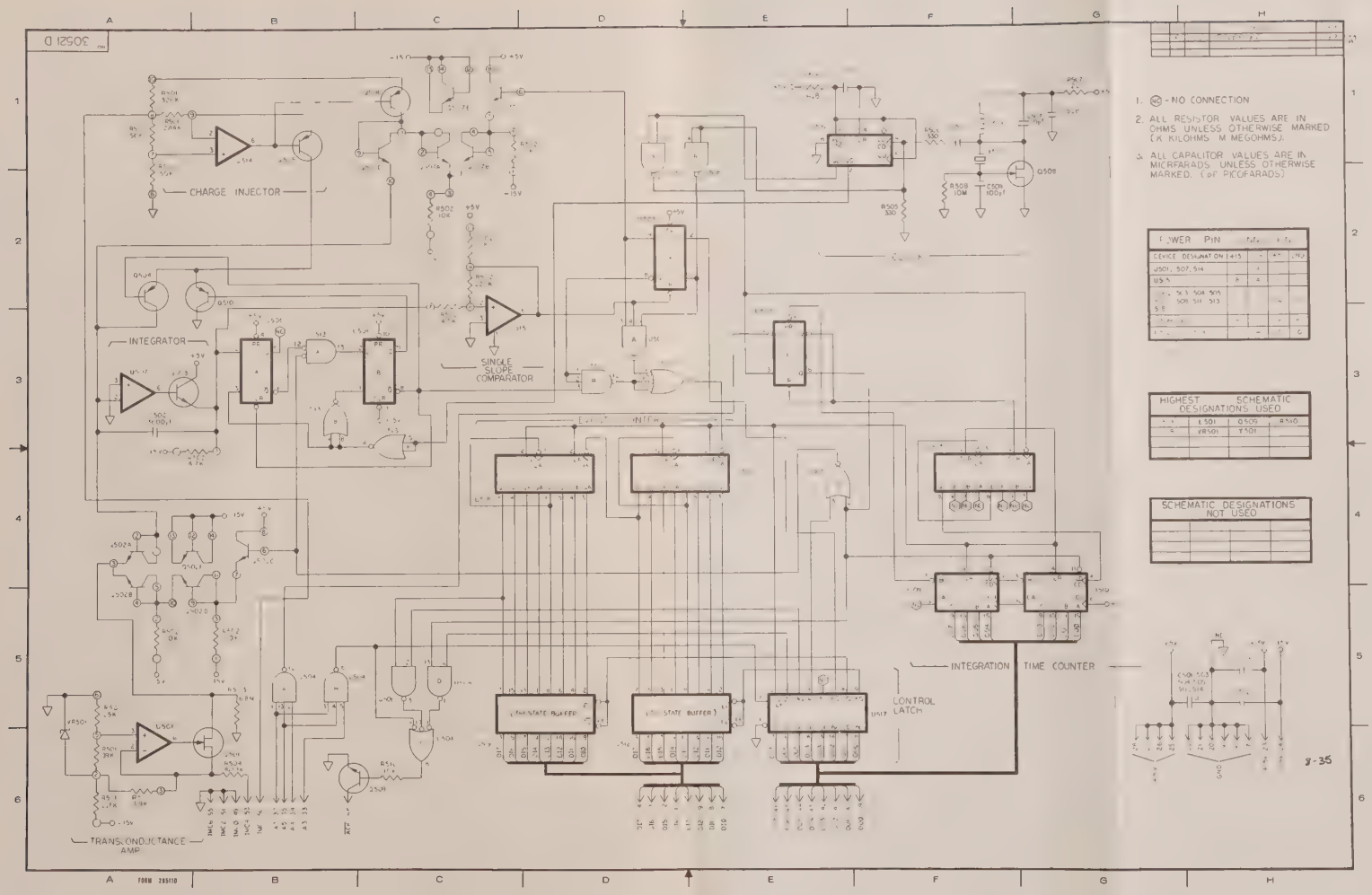

CHARGE INJECTOR
INTEGRATOR
SINGLE SLOPE COMPARATOR
TRANSCONDUCTANCE AMP
INTEGRATION TIME COUNTER
CONTROL LATCH
1. NC - NO CONNECTION
2. ALL RESISTOR VALUES ARE IN OHMS UNLESS OTHERWISE MARKED (K, KILOHMS M MEGOHMS).
3. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE MARKED. (pF PICOFARADS)
POWER PIN
DEVICE DESIGNATION
HIGHEST SCHEMATIC DESIGNATIONS USED
SCHEMATIC DESIGNATIONS NOT USED
8-35

Figure 8-14. A/D Converter Board, Schematic Diagram, Drawing Number 30521

Table 8-7. Electrometer Module PC-523 and PC-522 Parts List

Circuit Desig.	Description	Schematic Location	Keithley Part No.
C601	Capacitor, 10μF, 350V, Aluminum Electrolytic	522/C2	C-312-10
C602	Capacitor, 10μF, 350V, Aluminum Electrolytic	522/C3	C-312-10
C603	Capacitor, 4.7μF, 350V, Aluminum Electrolytic	522/B2	C-240-4.7
C604	Capacitor, 4.7μF, 350V, Aluminum Electrolytic	522/B3	C-240-4.7
C605	Capacitor, .1μF, 250V, Metalized Polyester	522/D3	C-178-0.1
C606	Capacitor, 470μF, 16V, Aluminum Electrolytic	522/C4	C-313-470
C607	Capacitor, 470μF, 16V, Aluminum Electrolytic	522/C3	C-313-470
C608	Capacitor, 250μF, 25V, Aluminum Electrolytic	522/C4	C-314-250
C609	Capacitor, 250μF, 25V, Aluminum Electrolytic	522/C4	C-314-250
C610	Capacitor, .01μF, 500V, Ceramic Disc	522/C4	C-22-.01
C651	Capacitor, 150pF, 500V, Polystyrene	523/B4	C-138-150p
C653	Capacitor, .047μF, 250V, Metalized Polyester	523/B2	C-178-.047
C654	Capacitor, 10μF, 20V, Tantalum	523/D2	C-179-10
C655	Capacitor, 47pF, 500V, Polystyrene	523/B3	C-138-47p
C656	Capacitor, 5000pF, 500V, Polystyrene	523/B3	C-138-5000p
C657	Capacitor, 47pF, 500V, Polystyrene	523/B3	C-138-47p
C658	Capacitor, 10pF, 500V, Polystyrene	523/C5	C-138-10p
C659	Capacitor, 10μF, 20V, Tantalum	523/D3	C-179-10
C660	Capacitor, 10μF, 20V, Tantalum	523/D3	C-179-10
C661	Capacitor, .01μF, 500V, Ceramic Disc	523/C4	C-22-.01
C662	Capacitor, .01μF, 500V, Ceramic Disc	523/C3	C-22-.01
C663	Capacitor, 10μF, 20V, Tantalum	523/H3	C-179-10
C664	Capacitor, 10μF, 20V, Tantalum	523/F5	C-179-10
C665	Capacitor, 1μF, 50V, Ceramic Film	523/C4	C-237-1.0
C666	Capacitor, .001μF, 500V, Ceramic Disc	523/G5	C-22-.001
C667	Capacitor, .001μF, 500V, Ceramic Disc	523/G5	C-22-.001
C668	Capacitor, .001μF, 500V, Ceramic Disc	523/G5	C-22-.001
CR601	Diode, Silicon, 1N914	522/D3	RF-28
CR602	Rectifier, 1A, 1N4006	522/C2	RF-38
CR603	Diode, Silicon, 1N914	522/F2	RF-28
CR604	Rectifier, 1A, 1N4006	522/G3	RF-38
CR605	Rectifier, 1A, 1N4006	522/D3	RF-38
CR606	Rectifier, 1A, 1N4006	522/D3	RF-38
CR607	Rectifier, 1A, 1N4006	522/F3	RF-38
CR608	Rectifier, 1A, 1N4006	522/F3	RF-38
CR609	Rectifier, 1A, 1N4006	522/C2	RF-38
CR610	Rectifier, 1A, 1N4006	522/C3	RF-38
CR611	Rectifier, 1A, 1N4006	522/C3	RF-38
CR612	Rectifier, 1A, 1N4006	522/C3	RF-38
CR613	Rectifier, 1A, 1N4006	522/D2	RF-38
CR614	Rectifier, 1A, 1N4006	522/F2	RF-38
CR615	Diode, Silicon, 1N914	522/D2	RF-28
CR616	Diode, Silicon, 1N914	522/E2	RF-28
CR617	Diode, Silicon, 1N914	522/E2	RF-28
CR618	Diode, Silicon, 1N914	522/E2	RF-28
CR619	Diode, Silicon, 1N914	522/F2	RF-28
CR620	Diode, Silicon, 1N914	522/ER2	RF-28

Table 8-7. Electrometer Module PC-523 and PC-522 Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
CR621	Diode, Silicon, 1N914	522/G2	RF-28
CR622	Diode, Silcon, 1N914	522/G3	RF-28
CR623	Diode, Silicon, 1N914	522/G2	RF-28
CR624	Rectifier, 1.5A, PF40	522/C4	RF-46
CR625	Rectifier, 1.5A, PF40	522/C4	RF-46
CR626	Diode, Silicon, 1N914	523/F4	RF-28
CR653	Diode, Silicon, 1N914	523/F5	RF-28
CR654	Diode, Silicon, 1N914	523/E5	RF-28
CR655	Diode, Silicon, 1N914	523/F4	RF-28
CR656	Diode, Silicon, 1N914	523/F4	RF-28
CR657	Diode, Silicon, 1N914	523/F1	RF-28
CR658	Diode, SIlicon, 1N914	523/F2	RF-28
CR659	Diode, Silicon, 1N914	523/F2	RF-28
CR660	Diode, Silicon, 1N914	523/F2	RF-28
CR661	Diode, Silicon, 1N914	523/F3	RF-28
CR662	Diode, Silicon, 1N914	523/F3	RF-28
CR663	Diode, Silicon, 1N914	523/E3	RF-28
CR664	Diode, Silicon, 1N914	523/F5	RF-28
F601	Fuse, 2A, 250V, 3AG		FU-13
J601	Binding Post, Red		BP-11-2
J602	Binding Post, Black		BP-11-0
J651	Jack, Triax		CS-440
J652	Connector, Microphone		CS-32
K601	Relay	522/G3	RL-66
K602	Relay	522/G3	RL-66
K603	Relay	522/G2	RL-65
K651	Relay	523/B2,F1	RL-70
K652	Relay	523/B3,F1	RL-70
K653	Relay	523/B3,F2	RL-70
K654	Relay	523/B3,F2	RL-70
K655	Relay	523/B2,F4	RL-70
K656	Relay	523/B5,F4	RL-70
K657	Relay	523/B2,F4	RL-65
K658	Relay	523/C3,E5	RL-65
K659	Relay	523/C2,F4	RL-65
K660	Relay	523/D4,F2	RL-70
K661	Relay	523/D5,F3	RL-65
K662	Relay	523/D5,E3	RL-65
Q601	Transistor, NPN, 2N3439	522/D3	TG-93
Q602	Transistor, PNP, 2N5416	522/F3	TG-105
Q603	Transistor, NPN, 2N3439	522/D3	TG-93
Q604	Transistor, PNP, 2N5416	522/F3	TG-105
Q605	Transistor, NPN, 2N3904	522/E3	TG-47
Q606	Transistor, PNP, 2N3906	522/E3	TG-84
Q607	Transistor, NPN, 2N3904	522/H2	TG-47

Table 8-7. Electrometer Module PC-523 and PC-522 Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
Q608	Transistor, NPN, 2N3904	522/H3	TG-47
Q651	Transistor, NPN, 2N3904	523/G5	TG-47
R601	Resistor, 330kΩ, 10%, ½W, Composition	522/C2	R-1-330k
R602	Resistor, 330kΩ, 10%, ½W, Composition	522/G2	R-1-330k
R603	Resistor, 10kΩ, 5%, 10W, Metal Film	522/E3	R-133-10k
R604	Resistor, 10kΩ, 5%, 10W, Metal Film	522/E3	R-133-10k
R605	Resistor, .1Ω, .1%, 7.5W, Wire Wound	522/E5	R-262-0.1
R606	Resistor, 330kΩ, 10%, ½W, Composition	522/D2	R-1-330k
R607	Resistor, 10kΩ, 5%, ¼W, Composition	522/D2	R-76-10k
R608	Resistor, 330kΩ, 10%, ½W, Composition	522/F2	R-1-330k
R609	Resistor, 10kΩ, 5%, ¼W, Composition	522/F2	R-76-10k
R610	Resistor, 470Ω, 5%, ¼W, Composition	522/H3	R-76-470
R611	Resistor, 680Ω, 5%, ¼W, Composition	522/H2	R-76-680
R612	Resistor, 47Ω, 5%, ¼W, Composition	522/E3	R-76-47
R613	Resistor, 23.7Ω, 1%, 1/8W, Metal Film	522/E3	R-88-23.7
R614	Resistor, 2.4kΩ, 1%, 1/8W, Metal Film	522/E3	R-88-2.74k
R615	Resistor, 23.7Ω, 1%, 1/8W, Metal Film	522/E3	R-88-23.7
R616	Resistor, 47Ω, 5%, ¼W, Composition	522/E3	R-76-47
R617	Resistor, 2kΩ, 1%, 1/8W, Metal Film	522/F3	R-88-2k
R618	Resistor, 47Ω, 5%, ¼W, Composition	522/E3	R-76-47
R619	Resistor, 47Ω, 5%, ¼W, Composition	522/E3	R-76-47
R651	Potentiometer, 10Ω, 10%, ½W	523/B2	RP-111-10
R652	Potentiometer, 200Ω, 10%, ½W	523/B2	RP-111-200
R653	Potentiometer, 5kΩ, 10%, ½W	523/B3	RP-111-5k
R654	Potentiometer, 2MΩ, 10%, ½W	523/B3	RP-111-2M
R655	Potentiometer, 5kΩ, 10%, ½W	523/B4	RP-111-5k
R656	Potentiometer, 5kΩ, 10%, ½W	523/C5	RP-111-10k
R657	Potentiometer, 50Ω, 10%, ½W	523/C2	RP-111-50
R658	Resistor, 97.6Ω, .1%, ½W, Metal Film	523/B2	R-169-97.6
R659	Resistor, 10kΩ, 10W, Wire Wound	523/B2	R-221-10k
R660	Resistor, 998kΩ, .1%, ¼W, Metal Film	523/B3	R-264-998k
R661	Resistor, 4.7kΩ, 5%, ¼W, Composition	523/B3	R-76-4.7k
R662	Resistor, 99MΩ, .5%, ¼W, Metal Oxide	523/B3	R-269-99M
R663	Resistor, 9.8GΩ, 2%, 1½5W, Epoxy Coated	523/B4	R-289-9.8G
R664	Resistor, 10kΩ, 1%, 1/8W, Metal Film	523/B4	R-88-10k
R665	Resistor, 499kΩ, 1%, 1/8W, Metal Film	523/B5	R-88-499k
R666	Resistor, 90.0kΩ, 1%, 1/8W, Metal Film	523/C4	R-88-90.9k
R667	Resistor, 10kΩ, 5%, ¼W, Composition	523/C4	R-76-10k
R668	Resistor, 1MΩ, 1/8W, Metal Film	523/B5	R-88-1M
R669	Reistor, 10kΩ, 5%, ¼W, Composition	523/C4	R-76-10k
R670	Resistor, 402Ω, .1%, 1/10W, Metal Film	523/C2	R-263-402
R671	Resistor, 6.49kΩ, 1%, 1/8W, Metal Film	523/D2	R-88-6.49k
R672	Resistor, Selected 1%, 1/8W, Metal Film	523/C2	R-88-*
R673	Resistor, 2.15kΩ, 1%, 1/10W, Metal Film	523/C2	R-263-2.15k
R674	Resistor, 806Ω, 1%, 1/8W, Metal Film	523/D2	R-88-806
R675	Resistor, 10kΩ, 1%, 1/8W, Metal Film	523/C3	R-88-10k
R676	Resistor, 10kΩ, 1%, 1/8W, Metal Film	523/C3	R-88-10k
R677	Resistor, 3.65Ω, 1%, 1/8W, Metal Film	523/D2	R-88-3.65

Table 8-7. Electrometer Module PC-523 and PC-522 Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
R678	Resistor, 1kΩ, 5%, ¼W, Composition	523/A1	R-76-1k
R679	Potentiometer, 5kΩ, 10%, ½W	523/D4	RP-111-5k
R680	Potentiometer, 500Ω, 10%, ½W	523/E5	RP-111-500
R681	Resistor, 10kΩ, .1%, ½W, Composition	523/E5	R-287-10k
R682	Resistor, 898kΩ, .1%, 1¼W, Composition	523/E4	R-286-898k
R683	Resistor, 898kΩ, .1%, 1¼W, Composition	523/E4	R-286-898k
R684	Resistor, 4.7kΩ, 5%, ¼W, Composition	523/F5	R-76-4.7k
R685	Resistor, 22kΩ, 5%, ¼W, Composition	523/F5	R-76-22k
R686	Resistor, 4.7kΩ, 5%, ¼W, Composition	523/E5	R-75-4.7k
R687	Resistor, 1kΩ, 5%, ¼W, Composition	523/C4	R-76-1k
R688	Resistor, 100Ω, 5%, ¼W, Composition	523/C4	R-76-100
T601	Transformer	522/B2,3,4	TR-176
U651	IC, Op Amp, AD515k	523/C4	IC-241
U652	IC, Op Amp, 741	523/D2	IC-42
U653	IC, Op Amp, Selected 741	523/C3	IC-77
U654	IC, Octal Flip-Flop, 74LS374	523/G4	IC-242
U655	IC, Octal Flip-Flop, 74LS374	523/G2	IC-242
U656	IC, Triple-3 NAND Gate, 74LS10	523/G5	IC-155
U657	IC, Quad NAND Gate, 74LS00	523/E5	IC-163
U658	IC, Quad OR Gate, 7432	523/F3	IC-115
VR651	IC, Regulator, 8V, 7908	523/D3	IC-243
VR652	Zener Diode, 1N4577	523/D2	DZ-58
VR653	Zener Diode, 1N749A	523/C2	DZ-63

*Selected Value.

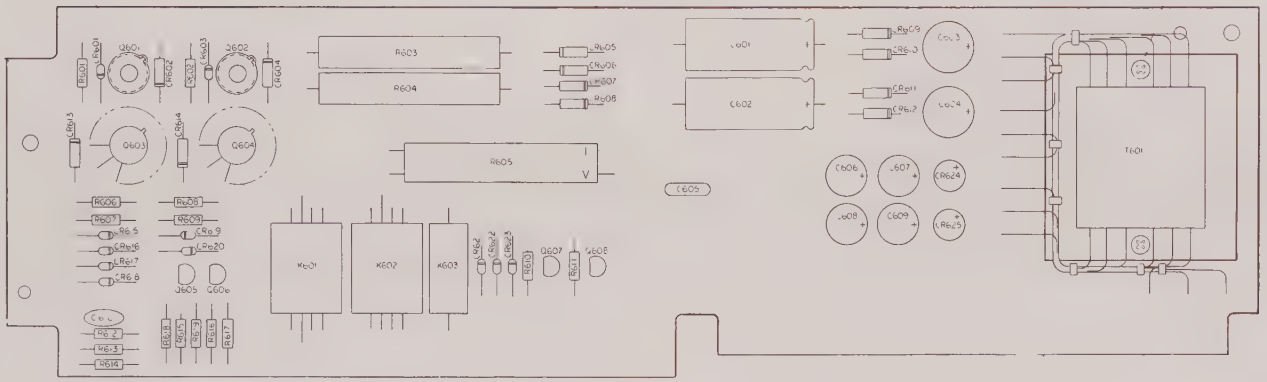


Figure 8-15. Electrometer Module PC-522, Component Location Drawing, Drawing Number 30387

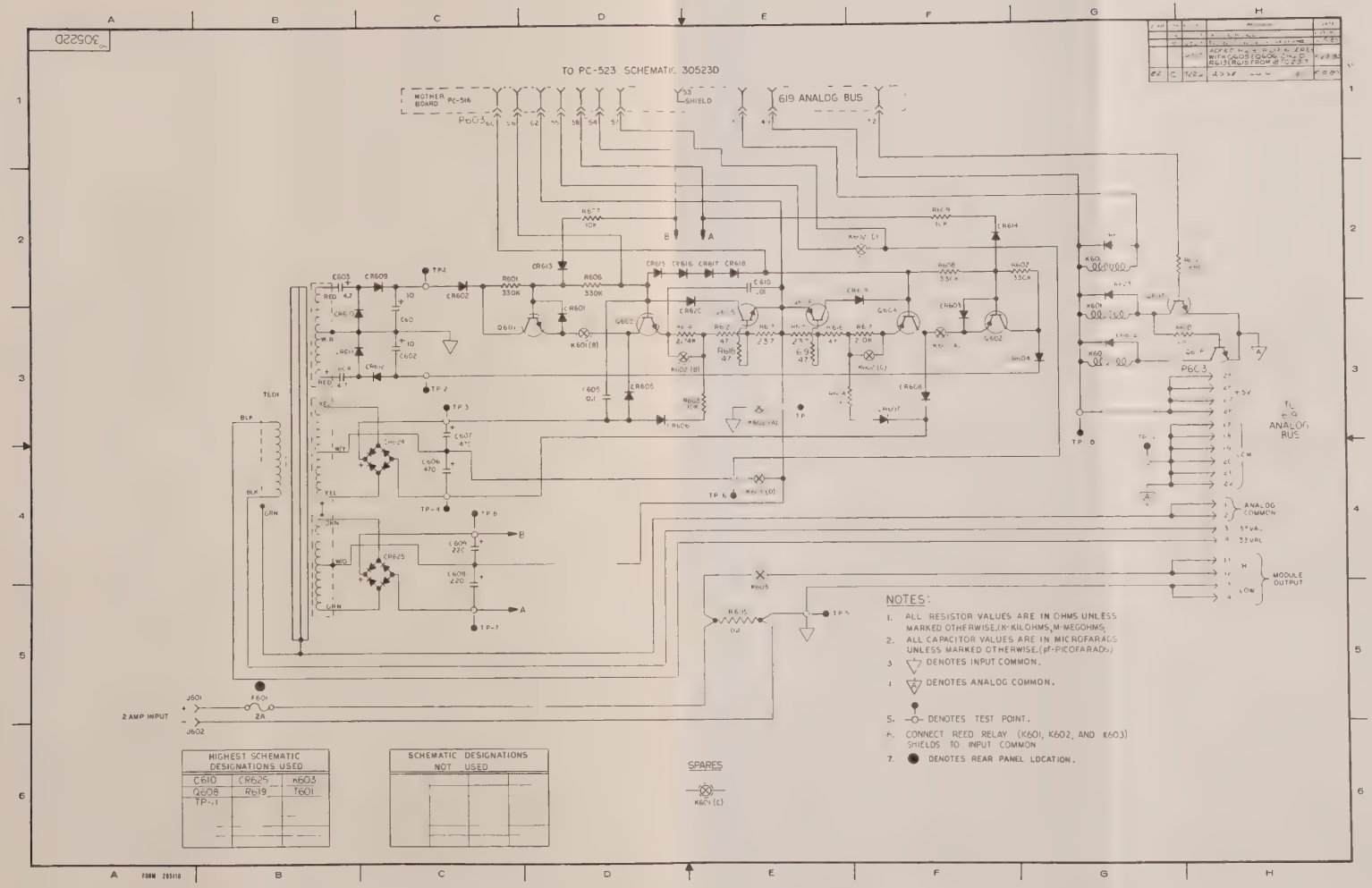


Figure 8-16. Electrometer Module PC—522, Schematic Diagram, Drawing Number 30522

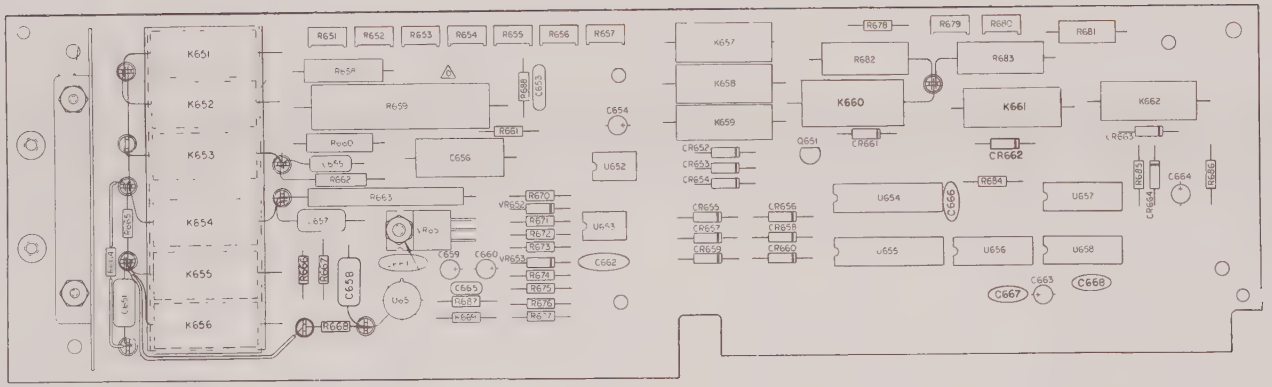


Figure 8-7. Electrometer Module PC-523, Component Location Drawing, Drawing Number 30391

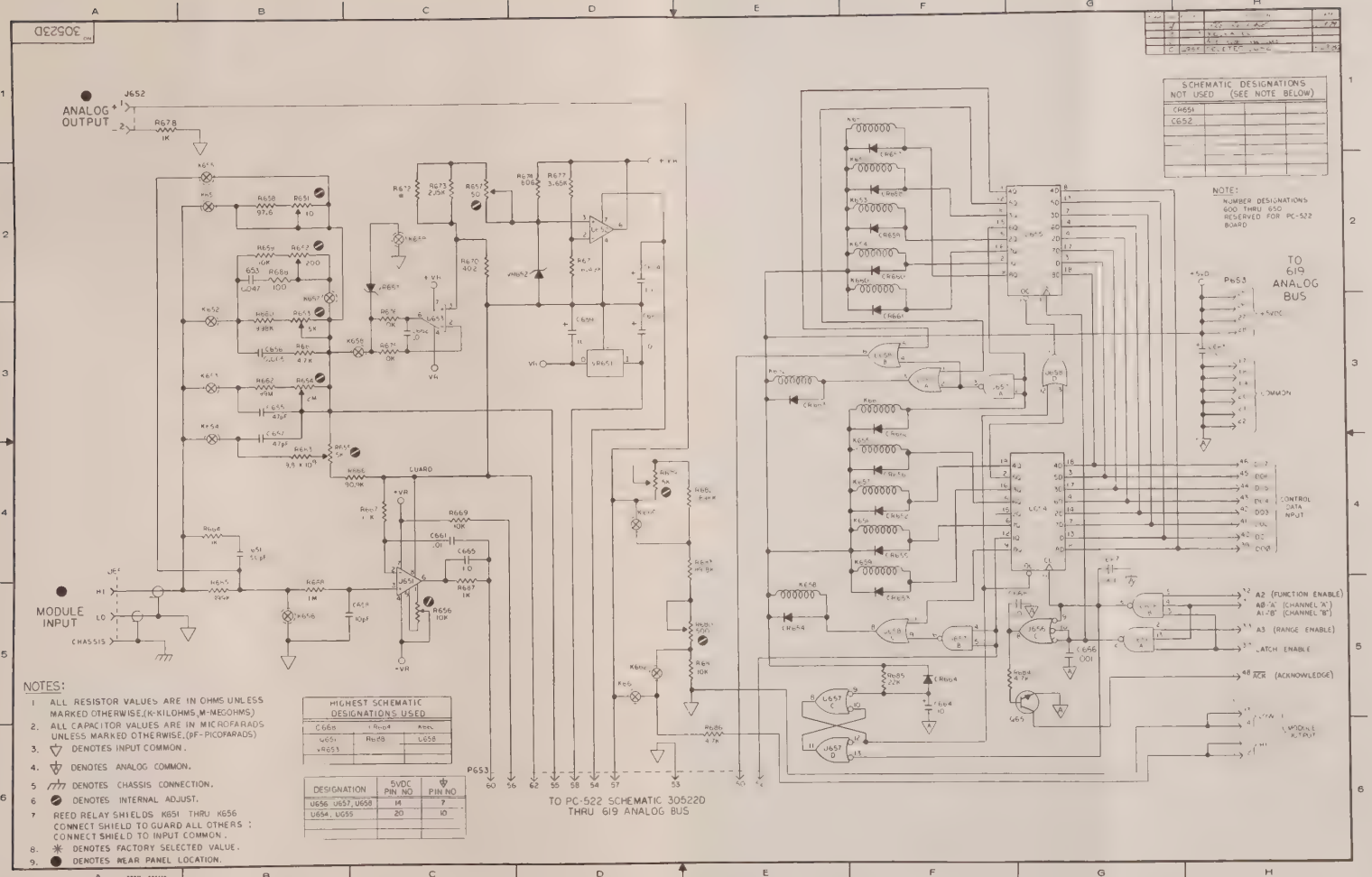

ANALOG OUTPUT
MODULE INPUT
CHASSIS
GUARD
TO PC-522 SCHEMATIC 30522D THRU 619 ANALOG BUS
TO 619 ANALOG BUS
SCHEMATIC DESIGNATIONS NOT USED (SEE NOTE BELOW)
NOTE: NUMBER DESIGNATIONS 600 THRU 650 RESERVED FOR PC-522 BOARD
HIGHEST SCHEMATIC DESIGNATIONS USED
NOTES:
1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE.(K-KILOHMS,M-MEGOHMS)
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE.(PF-PICOFARADS)
3. DENOTES INPUT COMMON.
4. DENOTES ANALOG COMMON.
5. DENOTES CHASSIS CONNECTION.
6. DENOTES INTERNAL ADJUST.
7. REED RELAY SHIELDS K651 THRU K656 CONNECT SHIELD TO GUARD ALL OTHERS : CONNECT SHIELD TO INPUT COMMON.
8. DENOTES FACTORY SELECTED VALUE.
9. DENOTES REAR PANEL LOCATION.
DESIGNATION
5VDC PIN NO
COMMON
CONTROL DATA INPUT
A2 (FUNCTION ENABLE)
A0 "A" (CHANNEL "A") A1 "B" (CHANNEL "B")
A3 (RANGE ENABLE)
LATCH ENABLE
ACK (ACKNOWLEDGE)

Figure 8-18. Electrometer Module PC-523, Schematic Diagram, Drawing Number 30523

Table 8-8. Filter Mux Board, Parts List

Circuit Desig.	Description	Schematic Location	Keithley Part No.
C401	Capacitor, .1μF, 50V, Ceramic Film	D2	C-237-.1
C402	Capacitor, .1μF, 16V, Ceramic Disc	G3	C-238-.1
C403	Capacitor, .1μF, 16V, Ceramic Disc	G4	C-238-.1
C404	Capacitor, .1μF, 16V, Ceramic Disc	E5	C-238-.1
C406	Capacitor, .1μF, 16V, Ceramic Disc	D5	C-238-.1
C407	Capacitor, .1μF, 16V, Ceramic Disc	C5	C-238-.1
C408	Capacitor, .47μF, 400V, Polypropylene	B1	C-323-.47
C409	Capacitor, .47μF, 400V, Polypropylene	B3	C-323-.47
C410	Capacitor, 1000pF, 500V, Polystyrene	B3	C-138-1000pF
C411	Capacitor, 1000pF, 500V, Polystyrene	B1	C-138-1000pF
C412	Capacitor, .1μF, 16V, Ceramic Disc	G5	C-237-.1
C413	Capacitor, .1μF, 16V, Ceramic Disc	G5	C-237-.1
CR401	Zener Diode, 6.3V	G3	DZ-58
CR402	Zener Diode, 6.3V	G4	DZ-58
CR403	Zener Diode, 5.1V	E1	DZ-59
CR404	Silicon Diode, 1N914	B4	RF-28
CR405	Silicon Diode, 1N914	B2	RF-28
CR406	Silicon Diode, 1N914	B2	RF-28
CR407	Silicon Diode, 1N914	B4	RF-28
CR408	Silicon Dlode, 1N914	C2	RF-28
K401	Relay	B2	RL-60
K402	Relay	B3,4	RL-60
K403	Relay	B2	RL-57
K404	Relay	B3,4	RL-57
K405	Relay	C2	RL-59
Q401	Transistor, NPN, 2N3904	G3	TG-47
Q402	Transistor, NPN, 2N3904	G4	TG-84
Q403	Transistor, NPN, 2N3904	F2	TG-47
Q404	Transistor, N-Channel FET, ITE4392	F3	TG-77
Q405	Transistor, N-Channel FET, ITE4392	F2	TG-77
Q406	Transistor, N-Channel FET, PF5301	D2	TG-139
Q407	Transistor, N-Channel FET, PF5301	E1	TG-139
Q408	Transistor, N-Channel FET, PF5301	E3	TG-139
Q409	Transistor, N-Channel FET, PF5301	E2	TG-139
Q410	Transistor, N-Channel FET, PF5301	E2	TG-139
Q411	Transistor, N-Channel FET, PF5301	E2	TG-139
Q412	Transistor, N-Channel FET,	E1	TG-139
Q413	Transistor, NPN, 2N3904	B5	TG-47
R401	Resistor, 100Ω, 5%, ¼W, Composition	C2	R-76-100
R402	Resistor, 2.74kΩ, 1%, 1/8W, Film	D3	R-88-2.74k
R403	Reistor, 6.04kΩ, 1%, 1/8W, Film	C3	R-88-6.04k
R404	Resistor, 10Ω, 5%, ¼W, Composition	G3	R-76-10
R405	Resistor, 10Ω, 5%, ¼W, Composition	G4	R-76-10
R406	Resistor, 4.7kΩ, 5%, ¼W, Composition	G2	R-76-4.7k

Table 8-8. Filter Mux Board, Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
U407	Resistor, 4.7kΩ, 5%, ¼W, Composition	G4	R-76-4.7k
R408	Resistor, 13.7kΩ, 1%, 1/8W, Film	C3	R-88-13.7k
R409	Resistor, selected with U402	D3	29996B
R410	Resistor, selected with U402	D3	29996B
R411	Potentiometer, 100kΩ	D4	RP-89-100k
R412	Resistor, 150kΩ, 1%, 1/8W, Film	D4	R-88-150k
R413	Resistor, 634kΩ, 1%, 1/8W, Film	E3	R-88-634k
R414	Resistor, Thick Film	D3,4	TF-84
R415	Potentiometer, 100Ω	D3	RP-89-100
R417	Resistor, 634kΩ, 1%, 1/8W, Film	E3	R-88-634k
R418	Resistor, 1kΩ, 1%, 1/8W, Film	F3	R-88-1k
R419	Resistor, 9.09kΩ, 1%, 1/8W, Film	F2	R-88-9.09k
R420	Resistor, 10kΩ, 1%, 1/8W, Film	G2	R-88-10k
R422	Resistor, 634kΩ, 1%, 1/8W, Film	D2	R-88-634k
R424	Resistor, 499kΩ, 1%, 1/8W, Film	C1	R-88-499k
R425	Resistor, 909kΩ, 1%, 1/8W, Film	D2	R-88-909k
R426	Resistor, 47kΩ, 5%, ¼W, Composition	E1	R-76-47k
R427	Resistor, Thick Film	Sev	TF-102-1
R428	Resistor, 1.5kΩ, 1%, 1/8W, Film	F5	R-88-1.5k
R429	Resistor, 3.48kΩ, 1%, 1/8W, Film	G5	R-88-3.48k
R430	Resistor, 10kΩ, 5%, ¼W, Composition	B5	R-76-10k
R431	Resistor, 10kΩ, 1%, 1/8W, Film	C2	R-88-10k
R432	Resistor, 10kΩ, 5%, ¼W, Composition	B3	R-76-10k
R433	Resistor, 30.1kΩ, 1%, ½W, Metal Film	B1	R-94-30.1k
R434	Resistor, 100kΩ, 1%, ½W, Metal Film	A3	R-94-100k
R435	Resistor, 10kΩ, 5%, ¼W, Composition	B1	R-76-10k
R436	Resistor, 30.1kΩ, 1%, ½W, Metal Film	B1	R-94-30.1k
R437	Resistor, 100kΩ, 1%, ½W, Metal Film	A1	R-94-100k
U401	IC, Op Amp, LF351N	D3	IC-176
U402	IC, Voltage Reference, selected with R409 and R410	D3	29996B
U403	IC, Op Amp, LF351N	F3	IC-176
U404	IC, Op Amp, LF356H	F1	IC-218
U405	IC, Op Amp, LF351N	D2	IC-176
U406	IC, Quad Comparator	Sev	IC-219
U407	IC, Quad Comparator	Sev	IC-219
U408	IC, Flip-Flop, 74LS374	E5	IC-242
U409	IC, Flip-Flop, 74LS374	D5	IC-242
U410	IC, Triple-3 Input NAND, 74LS10	C5	IC-155
W401	Jumper	E1	J-3
W402	Jumper	D2	22GA
W403	Jumper		J-3

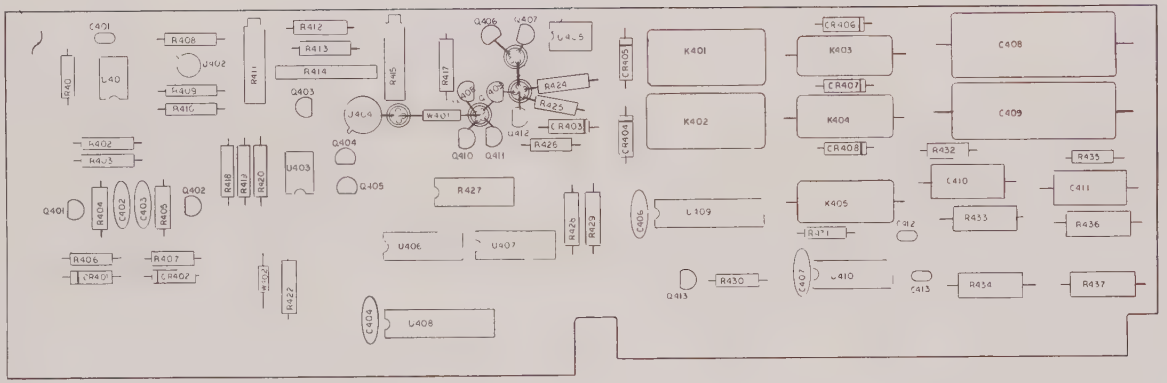


Figure 8-19. Filter Mux Board, Component Location Drawing, Drawing Number 30352

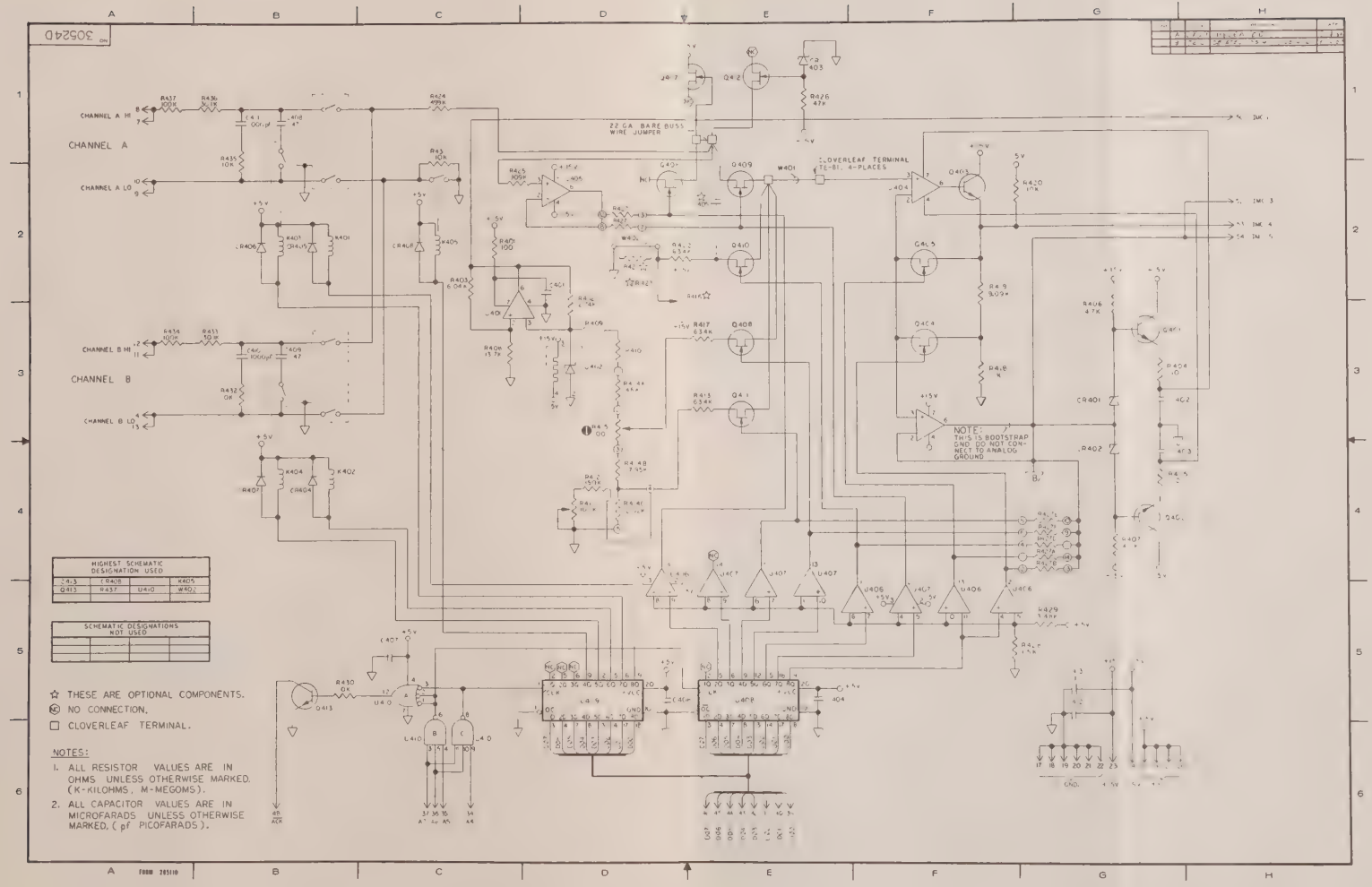

30524D
CHANNEL A HI
CHANNEL A
CHANNEL A LO
CHANNEL B HI
CHANNEL B
CHANNEL B LO
22 GA BARE BUSS WIRE JUMPER
CLOVERLEAF TERMINAL TE-81, 4-PLACES
NOTE: THIS IS BOOTSTRAP GND. DO NOT CONNECT TO ANALOG GROUND
HIGHEST SCHEMATIC DESIGNATION USED
SCHEMATIC DESIGNATIONS NOT USED
☆ THESE ARE OPTIONAL COMPONENTS.
NC NO CONNECTION.
□ CLOVERLEAF TERMINAL.
NOTES:
1. ALL RESISTOR VALUES ARE IN OHMS UNLESS OTHERWISE MARKED. (K-KILOHMS, M-MEGOMS).
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE MARKED, (pf PICOFARADS).

Figure 8-20. Filter Mux Board, Schematic Diagram, Drawing Number 30524

Table 8-9. Fan Assembly Parts List

Circuit Desig.	Description	Schematic Location	Keithley Part No.
J302	Power Connection	D5	CS-325-2
FAN	Fan	D5	FN-7
	Fan Assembly		30460C
	Fan Support Bracket		30453B
	Filter Support		30458A
	Filter*		FL-3*
	Grommet Strip		28479A-4
	Lug		LU-89

*Fan Filter must be kept clean.

Table 8-10. Mechanical Parts*

Qty	Description	Keithley Part No.
1	Base, Enclosure	30498E
1	Cover, Enclosure	30499E
1	Front Panel Assembly	32019C
1	Front Panel Overlay	30428D
6	Pushbutton (ZERO CHECK, ZERO CORRECT, BASELINE STORE, BASELINE SUPPRESSION, FILTER, RESOLUTION)	31470C-7
3	Pushbutton (AUTO MANUAL, UPRANGE, DOWNRANGE)	31470C-6
3	Pushbutton (VOLTS, AMPS OHMS)	31470C-5
4	Pushbutton (CHANNEL A, CAHNNEL B, RATIO A/B, DIFFERENCE A-B)	31470C-4
4	Rubber Foot	FE-6
1	Line Cord	CO-7

*Refer to Figure 7-11 for location of parts.

INDEX

Accessories, 1-4
Addenda, 1-1
Addressing
  Primary, 3-9
  Secondary, 3-10
Analog Output, 2-14
Applications, 4-1

Baseline
  Store, 2-23, 2-25, 3-29
  Suppression, 2-23, 2-25, 3-29
Beeper Programming, 7-3
Buffer Storage, 3-31
Bus Lines, IEEE-488, 3-1

Calibration, 7-4
Cautions, 1-2
Component Location Drawings, 8-1
Contents, Table of, i

Data Format, 3-23
Data Transmission Times, 3-37
Default Conditions, 3-16
Device Clear Command (DCL), 3-4, 3-15
Device-Dependent Command List, 3-18, 3-20
Disassembly Instructions, 7-11
Dual Channel Operation, 2-12

Electrometer Module, 1-5
Error Messages, 2-1, 3-9
Execute (X), 3-9
External
  Feedback, 2-18, 2-20
  Trigger, 2-16, 2-26, 3-27

Filter, 2-23, 2-25, 3-34
Front Panel
  Detailed Description, 2-2
  Displayed Messages, 2-1, 2-3
  Figure, 2-5
Function, 2-4, 3-21
Fuse, 7-2

Go To Local (GTL), 3-15
Group Execute Trigger (GET), 3-17

Handshake Sequence, 3-2

IEEE-488 Interface
  Address Selection, 3-9, 3-10
  Bus Set Up, 3-8
  Device-Dependent Commands, 3-5, 3-7
  General Description, 3-1
  Machine Status, 3-35
  SRQ, 3-32
  Status Byte, 3-32
Illustrations, List of, vi
Input Connections, 2-7
Interface Clear (IFC), 3-14
Internal Programming, 2-1, 7-2, 7-3

Line Voltage Selection, 7-1
Local Lockout, 3-14

Maintenance, 7-1
Maintenance Kit, 1-5
Measurement Consideration, 2-26
Machine Status
  Byte Definitions, 3-38
  Format, 3-36

Measurement Techniques
  Current, 2-8
  Resistance, 2-10
  Volts, 2-6

Operation, General, 1-3, 2-7

Performance Verification, 5-1
Power Up, 2-1, 7-14

Rack Mount Kits, 1-4
Range Selection, 2-4, 3-21
Reading Rate (S), 3-26, 7-3
Rear Panel
  Detailed Description, 2-3
  Figure, 2-5
Recommended Calibration Equipment, 7-4
Recommended Test Equipment, 5-1
Replaceable Parts
  Electrical, 8-1
  Mechanical, 7-12, 8-55
Resolution, 2-24

Safety Precautions
  Preceding Table of Contents
Safety Symbols and Terms, 1-1
Schematic Diagrams, 8-1
Selective Device Clear (SDC), 3-16
Self Test, 2-1
Serial Poll (SPE) (SPD), 3-17
Service Information, see Maintenance
Software Revision Level, 2-1
Specifications
  Amps, 1-2
  General, 1-2

Ohms, 1-2
Preceding Table of Contents
Volts, 1-2
Status Byte, 3-32
Status Word, 3-35

Tables, List of, viii
Terminator (Y), 3-34
Theory of Operation, 6-1
Trigger
External, 2-26
Electrometer Complete, 2-26
Troubleshooting Tables, 7-14, 7-15, 7-16, 7-18, 7-19

Uniline Commands, 3-3
Universal Commands, 3-4

Verification Procedure
Amps, 5-2
Ohms, 5-2
Volts, 5-2

Warm Up, 2-1, 2-7
Warnings, 1-2
Warranty, 1-1

Zero
Check, 2-22, 2-24, 3-28
Correct, 2-22, 2-24, 3-28

The number following each entry indicates the page number.

KEITHLEY

SERVICE FORM

Model No. _____ **Serial No.** _____ **P.O. No.** _____ **Date** _____

Name _____ **Phone** _____

Company _____

Address _____

City _____ **State** _____ **Zip** _____

List all control settings and describe problem. _____

_____

_____

_____ (Attach additional sheets as necessary.)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.) _____

What power line voltage is used? _____ Variation? _____

Frequency? _____ Ambient Temperature? _____ °F.

Variation? _____ °F. Rel. Humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe below.)

_____

_____

*Be sure to include your name and phone number on this service form.

MP MASTER
MA28544

KEITHLEY

Keithley Instruments, Inc./28775 Aurora Road/Cleveland, Ohio 44139/U.S.A./(216) 248-0400/Telex: 98-5469
WEST GERMANY: Keithley Instruments GmbH/Heiglhofstrasse 5/D-8000 München 70/314 289/Telex: 1345000
GREAT BRITAIN: Keithley Instruments, Ltd./1, Boulton Road/Reading, Berkshire RG2 ONL/(0734) 86 12 87/Telex: 847047
FRANCE: Keithley Instruments SARL/2 Bis, Rue Léon Blum/B.P. 60/91121 Palaiseau Cedex/(6) 0115 155/Telex: 600933
NETHERLANDS: Keithley Instruments BV/Arkelsedijk 4/NL-4206 AC Gorinchem/(01830) 25577/Telex: 24 684
SWITZERLAND: Keithley Instruments SA/Kriesbachstr. 4/CH-8660 Dübendorf/01 821 94 44/Telex: 57 536
AUSTRIA: Keithley Instruments Ges.m.b.H/Döblinger Hauptstr. 32/A-1190 Wien/0222 314 289/Telex: 134500